WATER & SEWAGE WORKS

REFERENCE *and* DATA EDITION

PART 2
MAY 1954

Water and Sewage Works Presents Its 1954 R & D Edition

For 19 Years
Water & Sewage Works magazine has issued
an annual reference and data section.

This Edition
is the first of these useful handbooks
to be published as a separate volume.

The Editors
have selected articles, tables and charts
relating to various phases of water supply,
sewerage and industrial waste problems.

The Contents
provide reference and data material of
value in project design and construction,
in operation, maintenance and management.

Information
presented in the 308 pages of this issue
includes much new material and a variety
of repeated material having basic value.

Subscribers
to Water & Sewage Works receive this new
reference and data edition without charge.

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reference and data edition

WATER & SEWAGE WORKS
reference and data edition

* MAY 1954

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CLASSIFIED INDEX OF PRODUCTS

For the Index to the Reference and Data Material, and the Index to Advertisers, See the Rear Section of this Issue.

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ACID SULFURIC AND HYDROCHLORIC

Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Maryland.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Tennessee Corp., 617-19 Grant Bldg., Atlanta, Ga.

2R

ACTIVATED AND BLACK ALUM

Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Maryland.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

3R

ACTIVATED CARBON

American Water Softener Co., 4th St. & Lehigh Ave., Philadelphia, Pa.
John Wiley Jones Co., 100 Sunny Sol Blvd., Caledonia, N. Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
West Virginia Pulp and Paper Co., Industrial Chemical Sales Division, 230 Park Avenue, New York 17, New York.

4R

AERATION APPARATUS

American Water Softener Co., 4th St. & Lehigh Ave., Philadelphia, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
The Dorr Co., Barry Place, Stamford, Conn.
Filtros, Inc., East Rochester, N. Y.
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Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Smith & Loveless, Inc., 62 Merriam Dr., Merriam, Kansas.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

5R

AGITATORS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
Link-Belt Co., Colmar, Pa.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Phipps & Bird, Inc., 303 S. Sixth Street, Richmond, Va.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Pross Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

AIR BLOWERS

(See Blowers, Air)

AIR COMPRESSORS

(See Compressors, Air)

6R

AIR RELIEF VALVES

Crane Co., 836 So. Michigan Ave., Chicago 5, Ill.
Darling Valve Co., Williamsport, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201 N. Talman Ave., Chicago, Ill.
P. S. Products Corp., Wayne Junction, Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

7R

ALTERNATORS, ELECTRIC

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Electric Mach. Mfg. Co., 800 Central Ave., Minneapolis 13, Minn.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kansas.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

ALUM

(See Black Alum or Filter Alum)

8R

AMMONIA, ANHYDROUS & AQUA

Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Maryland.
Penn Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

9R

AMMONIATORS

Amer. Water Softener Co., Philadelphia 33, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace & Tierman, Inc., 25 Main St., Bellevue, N. J.

10R

ANTHRAFILT

Amer. Water Softener Co., 4th & Lehigh Ave., Philadelphia 33, Pa.
Anthracite Equip. Co., Anthracite Institute Bldg., Wilkes-Barre, Pa.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

11R

AQUAPHONES

Aqua Survey & Instrument Co., 2518 Leslie Ave., Cincinnati 12, Ohio.
Northrup & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

12R

ARRESTERS, FLAME

H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

ASBESTOS-CEMENT PIPE

(See Pipe-Asbestos Cement)

13R

ASH AND COAL HANDLING MACHINERY

Bucyrus-Erie Co., South Milwaukee, Wis.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
Link-Belt Co., Colmar, Pa.
Oliver Corp., 400 W. Madison St., Chicago 6, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

BAR SCREENS

(See Screens, Sewage)

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BINS, Storage

Bethlehem Steel Co., Bethlehem, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
Link-Belt Co., Colmar, Pa.

15R

BITUMINOUS COATINGS AND LININGS

American Locomotive Co., Schenectady, N. Y.
Atlas Mineral Prod. Co., Mertztown, Pa.
Centriline Corp., 140 Cedar St., New York 6, N. Y.
Johns-Manville Corp., 22 East 40th Street, New York 16, New York
Koppers Company, Inc., 1301 Koppers Bldg., Pittsburgh 19, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Presstite Engineering Co., 3738 Choutau Ave., St. Louis 10, Mo.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

BLACK ALUM

(See Activated Alum)

BLEACHING POWDER

(See Calcium Hypochlorite)

16R

BLOWERS AIR, GAS (Centrifugal and Rotary)

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
General Electric Co., Schenectady, N. Y.
Homelite Corp., Port Chester, N. Y.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Roots-Connersville Blower Div. Dresser Industries, Inc., 900 W. Mount St., Connersville, Ind.
Worthington Corp., Harrison, N. J.

BOILER BREECHINGS

(See Breechings, Steel)

17R

BOILER FEEDWATER TREATMENT AND EQUIPMENT

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Water Softener Co., 4th St. & Lehigh Ave., Philadelphia, Pa.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Chain Belt Co., Milwaukee 1, Wis.
The Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Hellige, Inc., 37-18 Northern Blvd., Long Island City 1, N. Y.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Precision Machine Co., 8 Walnut St., Somerville 43, Mass.
Proportioneers, Inc., 345 Harris Ave., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Worthington Corp., Harrison, N. J.

18R

BOILERS, GAS

American Radiator & Standard Sanitary Corp., P. O. Box 1226, Pittsburgh 30, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.

19R

BOOKS, TECHNICAL

McGraw-Hill Book Co., 330 W. 42nd St., New York 18, N. Y.
The Macmillan Co., 60 Fifth Ave., New York 11, New York.
Phipps & Bird, Sixth & Bird St., Richmond, Va.
John Wiley & Sons, Inc., 440 4th Ave., New York 16, N. Y.

BOXES, VALVE AND METER

(See Valve Boxes; Meter Boxes)

20R

BRASS GOODS

(See also Pipe, Brass)

American Brass Co., 414 Meadow St., Waterbury 20, Conn.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., 215 W. Cerro Gordo St., Decatur 70, Ill.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., E. Orange, N. J.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

21R

BREECHING, STEEL

Bethlehem Steel Co., Bethlehem, Pa.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago.
R. D. Cole Mfg. Co., Newnan, Ga.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

22R

BRONZES (Special Alloy)

American Brass Co., 414 Meadow St., Waterbury 20, Conn.

23R

BUFFER SOLUTIONS & TABLETS

Beckman Instruments, Inc., South Pasadena 1, Calif.
General Laboratory Supply Co., P. O. Box 2607 Paterson, N. J.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

BUCKET ELEVATORS

(See Conveyors and Conveying Equip.)

BUTTERFLY VALVES

(See Valves, Butterfly)

24R

CABLE

Bethlehem Steel Co., Bethlehem, Pa.
General Electric Corp., 1 River Road, Schenectady, N. Y.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

25R

CALCIUM HYPOCHLORITE

John Wiley Jones Co., 100 Sunny Sol Blvd., Caledonia, N. Y.
Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Md.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Wallace & Tiernan, Inc., 25 Main St., Belleville, N. J.

CARBON-ACTIVATED
(See Activated Carbon)

26R

CARBONATORS (Recarbonation)
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Walker Process Equipment Inc., 840 N. Russell Ave., Aurora, Ill.

27R

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
Bethlehem Steel Co., Bethlehem, Pa.
Cast Iron Pipe Research Assoc., 122 So. Michigan Ave., Chicago.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 4, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
The Filer & Stowell Co., 147 E. Becher St., Milwaukee 7, Wis.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hardinge Mfg. Co., 240 Arch St., York, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5.

CAST IRON PIPE
(See Pipe)

28R

CATHODIC PROTECTIVE SYSTEMS
Chicago Bridge & Iron Co., 332 South Michigan Ave., Chicago.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Electro Rust-Proofing Corp., 30 Main St., Belleville 9, N. J.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.

29R

CAULKING MACHINES & TOOLS
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Mueller Co., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

30R

CEMENT ASBESTOS PIPE
Corey Mfgr. Co., 3279 Verdugo Rd., Los Angeles 65. Calif.
H. D. Fowler Co., Inc., 901 Lane St., (P. O. Box 3084), Seattle, Wash.
Johns-Manville, 22 E. 40th St., New York 16, N. Y.
Keasbey & Mattison Co., Ambler, Pa.

31R

CEMENT GUN
Cement Gun Co., Inc., 1520 Walnut Street, Allentown, Penna.

CEMENT LINED PIPE
(See Pipe, Cement Lined)

32R

CEMENT LINING OF PIPE
Centriline Corp., 140 Cedar St., New York 6, N. Y.
Pipe Linings, Inc., 4675 Firestone Blvd., South Gate, Calif.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

33R

CEMENTS, ACID PROOF & ALKALI PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.

34R

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York 16, N. Y.
Norton Co., New Bond St., Worchester 6, Mass.
Phipps & Bird, Sixth & Byrd St., Richmond, Va.

35R

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.

36R

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.

37R

CHAINS (Elevating, Conveying and Power Transmission)
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
Link-Belt Co., Colmar, Pa.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.

CHEMICAL CONTROL EQUIP.
(See Laboratory Apparatus and Reagents)

38R

CHEMICAL, CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee 1, Wis.
Hardinge Co., Inc., 240 Arch St., York, Pa.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
Link-Belt Co., Colmar, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Wallace & Tiernan, Box 178, Newark 1, N. J.

39R

CHEMICAL FEEDING AND PROPORTIONING EQUIPMENT (Dry and Solution—Also see Chlorinators)
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P.O. 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Hills-McCanna Co., 2357 W. Nelson St., Chicago 18, Ill.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold, 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt, Colmar, Pa.
Manzel Div., Frontier Industries, 315 Babcock St., Buffalo 10, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Omega Machine Co., 345 Harris Avenue, Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Precision Machine Co., 8 Walnut St., Somerville 43, Mass.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.
Wallace and Tiernan, Inc., 25 Main St., Belleville, N. J.

40R

CHLORINATORS
(See also Hypochlorinators)
Amer. Water Softener Co., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Builders - Providence, Inc., 350 Harris Ave., Providence, R. I.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Manzel Div., Frontier Industries, 315 Babcock St., Buffalo 10, N. Y.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Precision Machine Co., 8 Walnut St., Somerville 43, Mass.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
Wallace and Tiernan, Inc., 25 Main St., Belleville, N. J.

CHLORINE CONTROL EQUIPMENT
(See Residual Chlorine Control)

CHLORINE DIOXIDE
(See Sodium Chlorite)

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CHLORINE, LIQUID
John Wiley Jones Co., 100 Sunny Sol Blvd., Caledonia, N. Y.
Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Maryland.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Solvay Process Div., Allied Chemical & Dye Corp., 61 Broadway, New York 6, N. Y.

42R

CLAMPS AND SLEEVES, PIPE
Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., Decatur 70, Ill.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

43R

CLAMPS, BELL JOINT
Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
H. Y. Carson Co., 1221 Pinson St., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Corey Mfg. Co., 3279 Verdugo Rd., Los Angeles 65, Calif.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
M. B. Skinner Co., Sample St., South Bend, Ind.

44R

CLAMPS, PIPE REPAIR
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Corey Mfg. Co., 3279 Verdugo Rd., Los Angeles 65, Calif.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Joseph G. Pollard Co., New Hyde Park, N. Y.
Mueller Co., Decatur 70, Ill.
M. B. Skinner Co., Sample St., South Bend, Ind.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

45R

CLARIFIERS, SEWAGE AND WATER
American Water Softener Co., 4th St. & Lehigh Ave., Philadelphia, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., Colmar, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Walker-Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

CLAY PIPE
(See Vitrified Clay Pipe and Products)

CLEANING SOLUTIONS, CHLORINATORS
(See Chlorinators, Cleaning Solutions)

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CLEANING WATER MAINS
Flexible Sewer-Rod Equipment Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York 7, N. Y.
Robinson Pipe Cleaning Corp., Box 300, Canonsburg, Pa.
Southeastern Contracting Co., Box 9068, Birmingham 9, Ala.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

47R

COAGULATING AIDS
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Wallace & Tiernan, Inc., 25 Main St., Belleville, N. J.

COAL AND ASH HANDLING MACHINERY
(See Ash and Coal Handling Machinery)

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COATINGS, ACID AND ALKALI-PROOF
Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.
Atlas Mineral Products Co., Mertztown, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
Heresite & Chemical Co., Manitowoc, Wis.
Johns-Manville Corp., 22 East 40th St., New York 16.

Koppers Company, Inc., 1301 Koppers Bldg., Pittsburgh 19, Pa.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.

COATINGS AND LININGS
(See Bituminous Coatings and Linings)

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COCKS (Curb, Meter, Corporation, Etc.)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Homestead Valve Mfg. Co., Box 42, Coraopolis, Pa.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

COLLECTORS (Sludge)
(See Sludge Collectors)

COLORIMETERS
(See Photoelectric Colorimeters)

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COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 6th & Byrd Sts., Richmond, Va.

51R

COMMINUTING DEVICES
(See Grinders also)
American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
The Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Process Engineers Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Worthington Corp., Harrison, N. J.

52R

COMPARATORS, COLOR
General Laboratory Supply Co., P. O. Box 2607, Paterson, N. J.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace and Tiernan, Inc., 25 Main St., Belleville, N. J.

COMPOUNDS, JOINT
(See Jointing Compounds and Materials)

53R

COMPRESSORS, AIR
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Roots-Connersville Blower Div., Dresser Industries, Inc., 900 W. Mount St., Connersville, Ind.
Worthington Corp., Harrison N. J.

54R

CONCRETE BREAKERS
Homelite Corp., Port Chester, N. Y.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Worthington Corp., Harrison, N. J.

55R

CONCRETE HARDENER
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Solvay Process Div., Allied Chemical & Dye Corp., 61 Broadway, New York, N. Y.

56R

CONCRETE MIXER
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Worthington Corp., Harrison N. J.

57R

CONCRETE PIPE (Water and Sewage)
American Concrete Pressure Pipe Assn., 228 N. LaSalle St., Chicago 1, Ill.
Lock-Joint Pipe Co., P.O. Box 269, East Orange, N. J.
Price Bros. Co., 1932 E. Monument Ave., Dayton 1, Ohio.

58R

CONDENSERS (Steam)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Blackburn-Smith Mfg. Co., Inc., 55 Garden St., Hoboken, N. J.
R. D. Cole Mfg. Co., Newnan, Ga.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison, N. J.

59R

CONTRACTORS (Water and Sewage Works)
Cement Gun Co., P.O. Box 424, Allentown, Pa.
Layne & Bowler, Inc., Box 6697, Hollywood Sta., Memphis 8, Tennessee.
Ranney Method Water Supplies, Inc., P.O. Box 5415, Columbus 19, Ohio
Roberts Filter Mfg. Co., Darby, Pa.
Welsbach Corp., Cons. Div., 1500 Walnut St., Philadelphia 2, Pa.

60R

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 350 Harris Ave., Providence, R. I.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Healy-Ruff Co., 2255 University Ave., St. Paul 14, Minn.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Phipps & Bird, Inc., 6th & Byrd Sts., Richmond, Va.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kansas
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

61R

CONVEYORS AND CONVEYING EQUIPMENT
American Well Works, 100 N. Broadway, Aurora, Ill.
Builders-Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Gruendler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N. Y.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Oliver Corp., 400 W. Madison St., Chicago 6, Ill.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip. Inc., P. O. Box 266, Aurora, Ill.

62R

COPPER SULFATE
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Tennessee Corp., 617-29 Grant Bldg., Atlanta 1, Ga.

63R

COPPER TUBING AND RED BRASS PIPE
The American Brass Co., 414 Meadow St., Waterbury 20, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Mueller Co., Decatur 70, Ill.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

CORPORATION & CURB COCKS
(See Cocks-Corporation, Curb and Meter)

64R

CORROSION SUPPRESSION
American Water Softener Co., 4th St. & Lehigh Ave., Philadelphia, Pa.
Calgon, Inc., Hagan Bldg., 323 4th Ave., Pittsburgh 22, Pa.
Dresser Mfg. Div., 41 Fisher Ave., Bradford, Pa.
Electro Rust-Proofing Co., 30 Main St., Belleville, N. J.

65R

COUPLINGS & CONNECTIONS, PIPE
Alabama Pipe Co., Box 791, Anniston, Ala.
James P. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Johns-Manville, 22 E. 40th St., New York 16, N. Y.
Kraloy Plastic Pipe Co., 4720 E. Washington Blvd., Los Angeles, Calif.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

66R

COUPLINGS, FLEXIBLE
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Link-Belt Co., Colmar, Pa.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

CULVERT PIPE
(See Pipe, Culvert)

67R

CURB BOXES
Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
Art Concrete Works, 366 S. Fair Oaks Ave., Pasadena, Calif.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Filtration Equip. Corp., 271 Hallenbeck St., Rochester 21, N. Y.
Kennedy Valve Mfg. Co., Elmira N. Y.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

68R

DECHLORINATING EQUIPMENT AND CHEMICALS
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave., & 4th St., Philadelphia 33, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Tennessee Corp., 617-29 Grant Bldg., Atlanta, Ga.
Wallace and Tiernan, Inc., 25 Main St., Belleville, N. J.

69R

DE-MINERALIZATION EQUIPMENT (Water)
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, 303 S. Sixth St., Richmond, Va.

DEODORIZING
(Service, Equipment, Chemicals, etc.)
Airkem, Inc., 241 E. 44th St., New York 17, N.Y.
Reliance Chemicals Corp., Box 6724, Houston 5, Texas

DIAPHRAGM, PUMP
(See Pumps, Diaphragm)

70R

DIATOMITE FILTER SEPTUMS
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Carborundum Co., Perth Amboy, N. J.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.

Proportioneers, Inc., 345 Harris Ave., Providence, R. I.

DIESEL ENGINES
(See Engines, Diesel)

71R
DIFFUSERS—PLATES, TUBES AND FITTINGS
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Filtros Inc., East Rochester, N. Y.
Link-Belt Co., Colmar, Pa.
Norton Co., New Bond St., Worchester 6, Mass.
Walker Process Equipment, Inc., 840 N. Russell Ave., Aurora, Ill.

72R
DIGESTER EQUIPMENT (Sludge)
American Well Works, 100 N. Broadway, Aurora, Ill.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Hardinge Co., 240 Arch St., York, Pa.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Link-Belt Co., Colmar, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

73R
DISTRIBUTORS (Sewage Filter)
American Well Works, 100 N. Broadway, Aurora, Ill.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., Colmar, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kans.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

74R
DRAINS, GUTTER, FLOOR
Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.

75R
DRILLING AND BORING EQUIPMENT
Bucyrus-Erie Co., South Milwaukee, Wis.

DRIVES, CHAIN
(See Chains)

76R
DRIVES, RIGHT ANGLE GEAR
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link-Belt Co., Colmar, Pa.
Payne Dean Co., Madison, Conn.
U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.
Worthington Corp., Harrison, N. J.

77R
DRIVES, V-BELT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Link-Belt Co., Colmar, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Worthington Corp., Harrison, N. J.

78R
DRYING SYSTEMS (Sludge)
R. D. Cole Mfg., Newnan, Ga.
Combustion Engineering, Inc., 200 Madison Ave., New York, N. Y.
Dorr Co., Barry Place, Stamford, Conn.
Gen. Amer. Transp. Co., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Komline-Sanderson Engr. Corp., Peapack, N. J.
Link Belt Co., Colmar, Pa.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N. Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5.
Reliance Chemicals Corp., Box 6724, Houston, Texas

79R
EARTH MOVING EQUIPMENT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Bucyrus-Erie Co., South Milwaukee, Wis.
Link Belt Co., Colmar, Pa.
Oliver Corp., 400 W. Madison St., Chicago 6, Ill.

80R
EJECTORS, PNEUMATIC or STEAM (For Sewage and Sludge)
Blackburn-Smith Mfg. Co., Inc., 55 Garden St., Hoboken, N. J.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
H. D. Fowler Co., Inc., 901 Lane St., Seattle, Wash.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kans.
Stuart Corp., 516 N. Charles St., Baltimore 1. Md.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison N. J.

81R
ELECTRICAL CONTROL EQUIPMENT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
The Foxboro Co., 38 Naponset Ave., Foxboro, Mass.
General Electric Corp., 1 River Road, Schnectady, N. Y.
Healy-Ruff Co., 2255 University Ave., St. Paul 14, Minn.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kans.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

ELECTRICALLY OPERATED GATE VALVES
(See Valves, Motor Operated)

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment)

82R
ENGINE-GENERATOR UNIT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Riverdale Ave., Port Chester, N. Y. (Gasoline Engine Driven and Portable)
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
National Supply Co., Box 416, Pittsburgh 30, Pa.
Westinghouse Electric Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison, N. J.

83R
ENGINES DIESEL
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
The National Supply Co., P. O. Box 416, Pittsburgh 30, Pa.
Oliver Corp., 400 W. Madison St., Chicago 6, Ill.
Worthington Corp., Harrison, N. J.

84R
ENGINES, DUAL FUEL
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
The National Supply Co., P. O. Box 416, Pittsburgh 30, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Worthington Corp., Harrison, N. J.

85R
ENGINES (Gas & Gasoline)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
National Supply Co., Box 416, Pittsburgh 30, Pa.
Oliver Corp., 400 W. Madison St., Chicago 6, Ill.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Worthington Corp., Harrison, N. J.

86R
ENGINES, SLUDGE GAS
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
National Supply Co., Box 416, Pittsburgh 30, Pa.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Worthington Corp., Harrison, N. J.

EXPANSON JOINTS—PIPE
(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR
(See Pump, Vacuum)

87R
FANS, EXHAUST AND VENTILATNG
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

FEED, CHEMICAL
(See Chemical Feeding Equipment)

88R
FEED WATER HEATERS AND FILTERS
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Worthington Corp., Harrison, N. J.

89R
FENCE (Chain Link)
Continental Steel Corp., 1109 S. Main St., Kokomo, Ind.

90R
FERRIC CHLORIDE
Penn. Salt Mfg. Co., 100 Widener Bldg., Philadelphia 7, Pa. (Liquid)
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

FERRIC CHLORIDE FEEDERS
(See Chemical Feed and Proportioning Equipment)

91R
FERRIC SULPHATE
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Tennessee Corp., 617-29 Grant Bldg., Atlanta 1, Ga.

FIBRE PIPE
(See Pipe, Fibre)

92R
FILTER AIDS
Johns-Manville Co., 22 E. 40th St., New York, N. Y.

93R
FILTER ALUM
Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Md.
Penn Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

94R
FILTER EQUIPMENT
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Blackburn-Smith Mfg. Co., Inc., 55 Garden St., Hoboken, N. J.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
R. D. Cole Mfg., Newnan, Ga.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Filtration Equip Corp., 271 Hollenbeck St., Rochester 21, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Komline-Sanderson Engr. Corp., Peapack, N. J.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Norton Co., New Bond St., Worchester 6, Mass.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kans.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip. Co., Aurora, Ill.
Worthington Corp., Harrison, N. J.

95R
FILTER MEDIA
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Anthracite Equipment Co., Anthracite Institute Bldg., Wilkes-Barre, Pa.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Carborundum Co., Perth Amboy, N. J.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.

Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Norton Co., New Bond St., Worchester 6, Mass.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Roberts Filter Mfgr. Co., Darby, Pa.

96R

FILTER PLATES AND TUBES

American Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Filtros, Inc., East Rochester, N. Y.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.

FILTER RATE CONTROLLERS & GAGES

(See Rate Controllers.)

97R

FILTER UNDERDRAINS, SEWAGE

American Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Filtros, Inc., East Rochester, N. Y.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

98R

FILTER UNDERDRAINS, WATER

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
The Carborundum Co., Perth Amboy, N. J.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Filtration Equip. Corp., 271 Hollenbeck St., Rochester 21, N. Y.
Filtros, Inc., East Rochester, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Nat'l. Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.
Norton Co., New Bond St., Worchester 6, Mass.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equipment, Inc., P. O. Box 266, Aurora, Ill.

99R

FILTERS VACUUM

General American Process Equip. Div., Gen. Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Komline-Sanderson Engr. Corp., Peapack, N. J.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia 42, Pa.

100R

FITTINGS, PIPE, SOLDER TYPE

Alabama Pipe Co., Box 791, Anniston, Ala.
The American Brass Co., 25 Broadway, New York 4, New York.
Bethlehem Steel Co., Bethlehem, Pa.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Lock Joint Pipe Co., P. O. Box 269, E. Orange, N. J.
Johns-Manville Corp., 22 East 40th St., New York 16.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.
Yardley Plastic Co., 142 Parsons Ave., Columbus 15, Ohio.

101R

FITTINGS, TEES, ELLS, ETC.

Alabama Pipe Co., P. O. Box, 791 Anniston, Ala.
American Cast Iron Pipe Co., 2930 N. 16th St., Birmingham 2, Ala.
American Locomotive Co., Schenectady, N. Y.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Continental Can Co., Mills Plastic Pipe Div., 100 E. 42nd St., New York 17, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
The Kennedy Valve Mfg. Co., P. O. Box 931, Elmira, N. Y.
Kraloy Plastic Pipe Co., Inc., 4710-20 E. Washington Blvd., Los Angeles 22, Calif.
McWane Cast Iron Pipe Co., P. O. Box 2601, Birmingham 2, Ala.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
Smith-Blair, Inc., 535 Railroad Ave., So. San Francisco, Calif.
U. S. Pipe & Foundry Co., 3300 First Ave., North Birmingham 2, Ala.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

FLASH MIXING EQUIPMENT

(See Mixers & Mixing Equipment.)

FLEXIBLE JOINTS

(See Joints, Flexible Pipe.)

102R

FLOATING COVERS (Digester)

Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Illinois.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

103R

FLOCCULATING EQUIPMENT

American Well Works, 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes, Inc., 295 Madison Ave., New York 17, N. Y.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., Colmar, Pa.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Precision Machine Co., 8 Walnut St., Somerville 43, Mass.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Reliance Chemicals Corp., Box 6724, Houston 5, Texas
Roberts Filter Mfg. Co., Darby, Pa.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kans.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

FLOORING

(See Gratings)

104R

FLOW METERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Leupold & Stevens Insts., Inc., 4445 N. E. Gibson St., Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.
Simplex Value & Meter Co., 68th & Upland Sts., Philadelphia 42, Pa.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.

FLOW RECORDERS

(See Rate of Flow Recorders)

FLOW REGULATORS

(See Rate of Flow Controllers)

105R

FLUMES, IRON & STEEL

Bethlehem Steel Co., Bethlehem, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

106R

FLUORIDATION CHEMICALS

John Wiley Jones Co., 100 Sunny Sol Blvd., Caledonia, N. Y.
Phipps & Bird, Sixth & Byrd Sts., Richmond, Va.
Tennessee Corp., 617-29 Grant Bldg., Atlanta, Ga.

107R

FLUORIDATION EQUIPMENT

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave., & 4th St., Philadelphia 33, Pa.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Omega Machine Co., 345 Harris Ave., Providence, R. I.
Proportioneers, Inc., 350 Harris Ave., Providence, R. I.
Wallace & Tiernan, Inc., 25 Main St., Belleville, N. J.

FOOT VALVE WITH STRAINER

(See Valves, Foot)

108R

FORMS & GASKETS FOR PIPE JOINTS

Northrup & Co., Inc., Spring Valley, N. Y.

109R

FURNACES (Melting, Pouring Ladles, Pots, Etc.)

Atlas Mineral Products Co., Mertztown, Pa.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
General Laboratory Supply Co., P. O. Box 2607, Paterson, N. J.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Phipps & Bird, Sixth & Byrd Sts., Richmond, Va.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
W. S. Rockwell Co., Fairfield, Conn.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

110R

GAGES (Liquid Level, Pressure Recording)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco, Inc., P. O. Box 5033 Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.

GARBAGE GRINDERS

(See Grinders)

111R

GAS DIFFUSERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Carborudum Co., Perth Amboy, N. J.
Filtros, Inc., East Rochester, N. Y.
Norton Co., New Bond St., Worchester 6, Mass.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

GAS ENGINES

(See Engines, Gas)

112R

GATES, FENCE (Steel)

Continental Steel Corp., Kokomo Ind.

113R

GAS HOLDERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Bethlehem Steel Co., Bethlehem, Pa.
Chicago Bridge & Iron Company, 332 S. Michigan Ave., Chicago.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
The Dorr Company, Barry Place, Stamford, Conn.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25.
Process Engineers, Inc., 321 Market St., San Francisco, Calif.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

114R

GAS INDICATOR AND DETECTORS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.

115R

GATES, SHEAR

Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Eddy Valve Co., Waterford, N. Y.
Filtration Equip. Corp., 271 Hollenbeck St., Rochester 21, N. Y.
Rodney Hunt Machine Co., 84 Lake St., Orange, Mass.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.

116R

GATES, SLUICE

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
James B. Clow Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
R. D. Cole Mfg., Newnan, Ga.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wis.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Rodney Hunt Machine Co., 84 Lake St., Orange, Mass.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
R.S. Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

117R

GATE VALVE OPERATOR

Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve and Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher St., Milwaukee 7, Wis.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Homestead Valve Mfg. Co., Box 42, Coraopolis, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., Inc., P. O. Box 388, Troy, N. Y.
M & H Valve & Fitting Co., Box 909, Anniston, Ala.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Payne Dean & Co., Madison, Conn.
A. P. Smith Mfg. Co., E. Orange, N. J.

GATE VALVES

(See Valves, Gate)

118R

GEARS, SPEED REDUCING

De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link-Belt Co., Colmar, Pa.
U. S. Electrical Motors, Ins., 200 E. Slauson Ave., Los Angeles 54, Calif.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison, N. J.

119R

GEIGER COUNTERS

Beckman Instruments, Inc., 820 Mission St., South Pasadena, Calif.
Detectron Corp., 5420 Vineland Ave., No. Hollywood, Calif.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

120R

GENERATORS (Electric)

De Laval Steam Turbine Co., Trenton 2, N. J.
Electric Mach. Mfg. Co., 800 Central Ave., Minneapolis 13, Minn.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
General Electric Co., 1 River Road, Schenectady, N. Y.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison, N. J.

GENERATOR SETS, GAS & DIESEL ENGINES

(See Engine Generating Units)

121R

GOOSENECKS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
Worthington Corp., Harrison, N. J.

122R

GRATINGS, FLOORING, TREADS

Irving Subway Grating Co., Inc., 50-89 27th St., Long Island City 1, N. Y.

123R

GREEN SAND (See Zeolite)

Amer. Water Softener Co., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.

124R

GRINDERS, GARBAGE & SCREENINGS

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
Dorr Co., Barry Place, Stamford, Conn.
General Electric Co. (household), 1 River Road, Schenectady 5, N. Y.
Gruendler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link Belt Co., Colmar, Pa.
Walker Process Equipment, Inc., 840 N. Russell Ave., Aurora, Ill.
Westinghouse Elect. Corp. (household), Pittsburgh, Pa.
Worthington Corp., Harrison, N. J.

125R

GRIT CHAMBER EQUIPMENT & GRIT WASHERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

126R

GROUND KEY STOPS

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
The Ford Meter Box Co., Inc., Wabash, Ind.
Homestead Valve Mfg. Co., Box 42, Coraopolis, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
The Welsbach Corp., Kitson Valve Division, 1500 Walnut Street, Philadelphia 2, Pa.

127R

GUNITING CONTRACTNG

Cement Gun Company, Inc., 1520 Walnut Street, Allentown, Pa.

128R

HEATERS, DIGESTER

American Radiator & Standard Sanitary Corp., Box 1226, Pittsburgh 30, Pa.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

129R

HOSE, STEAM, AIR, WATER, SUCTON

The American Brass Co., 25 Broadway, New York 4, N. Y.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

HYDRANT PUMPS

(See Pumps, Hydrant)

130R

HYDRANTS (Fire)

Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Grinnell Co., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Ontario, Street, Troy, N. Y.
Ross Valve Mfg. Co., Inc., 4 Oakwood Ave., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

HYDRAULICALLY OPERATED GATE VALVES

(See Valves, Gate)

HYDROGEN ION EQUIPMENT

(See pH Test Equipment)

131R

HYPO-CHLORINATORS

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Manzel Div., Frontier Industries, 315 Babcock St., Buffalo 10, N. Y.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Precision Machine Co., 8 Walnut St., Somerville 43, Mass.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
Wallace and Tiernan, 25 Main St., Belleville, N. J.

HYPOCHLORITES (High Test)

(See Calcium Hypochlorite)

132R

INCINERATORS (Sludge and Garbage)

Combustion Engineering, Inc., 200 Madison Ave., New York, N. Y.
Dorr Co., Barry Place, Stamford, Conn.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N. Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.

133R

INDICATORS, LARGE DIAL, ILLUMINATED

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 2255 University Ave., St. Paul 14, Minn.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Leupold & Stevens Inst., 4445 N. E. Glissen, Portland, Ore.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6742 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

134R

INSECTICIDES

Koppers Co., Koppers Bldg., Pittsburgh 19, Pa.

135R

INSERTING SLEEVES, VALVE

James B. Clow, 201-209 N. Talman Ave., Chicago 80, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur 70, Ill.
A. P. Smith, 545 N. Arlington Ave., East Orange, N. J.

136R

INSULATION

Johns-Manville, 22 E. 40th St., New York 16, N. Y.
Keasbey & Mattison Co., Ambler, Penna.

IRON SULFATE

(See Ferric Sulfate, or Ferrous Sulfate)

137R

JOINTING COMPOUND AND MATERIALS

Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.

Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Koppers Co., Inc., 1301 Koppers Bldg., Pittsburgh 19, Pa.
Leadite Co., Philadelphia, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.
Prestite Engr. Co., 2738 Chouteau Ave., St. Louis 10, Mo.
Smith-Blair, Inc., 535 Railroad Ave., So. San Francisco, Calif.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.

138R

JOINTS, EXPANSION—PIPE

James B. Clow, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., 218 Gougler Ave., Kent, Ohio.
Johns-Manville Corp., 22 E. 40th Street, New York 16, N. Y.
Lock Joint Pipe Co., P. O. Box 269 East Orange, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.

139R

JOINTS, FLEXIBLE PIPE

Hamilton Kent Mfg. Co., Kent, Ohio.
James B. Clow & Sons, 201-299 N. N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
United States Pipe and Foundry Co., 3300 First Ave. North, Birmingham 2, Ala.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.

140R

JOINTS, MECHANICAL FLEXIBLE

Amer. Brass Co., Waterbury, Conn.
H. Y. Carson Co., 1221 Pinson St., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
The A. P. Smith Mfg. Co., East Orange, New Jersey.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City

141R

JUTE, BRAIDED AND TWISTED

Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

142R

LABORATORY APPARATUS, REAGENTS AND EQUIPMENT

Beckman Instruments, Inc., South Pasadena 1, Calif.
Calgon, Inc., 323 4th Ave., Hagan Bldg., Pittsburgh, Pa.
Combustion Engineering, Inc., 200 Madison Ave., New York 16, N.Y.
General Laboratory Supply Co., P. O. Box 2607, Paterson, N. J.
Grunedler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Infilco, Inc., P. O. Box 5023, Tucson, Ariz.
Kewaunee Mfg. Corp., 5102 S. Center St., Adrian, Mich.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Norton Co., New Bond St., Worchester 6, Mass.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan, Inc., 25 Main St., Belleville, N. J.

143R

LEAD, CAULKING

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

LEAK LOCATING INSTRUMENTS

(See Water Leak Locating Instruments)

LINING, TANKS (See Tanks, Lining)

LIQUID CHLORINE

(See Chlorine, Liquid)

144R

LOCATORS, BOX, PIPE AND VALVE

Aqua Survey & Instrument Co., 2518 Leslie Ave., Cincinnati 12, Ohio
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Wilkinson Products Co., 2987 Chevy Chase Drive, Pasadena 3, Calif.

145R

LUBRICANTS, VALVE

American Car and Foundry Co., Valve Div., 1501 Ferry Avenue East, Detroit, Mich.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.

146R

MANHOLE FRAMES, COVERS

Alabama Pipe Co., Box 791, Anniston, Ala.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
R. D. Cole Mfg., Newnan, Ga.
Grinnell Co., 260 W. Exchange St., Providence 1, R. I.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.

147R

MANOMETERS

Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Company, Dept. 9F, Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Wallace and Tiernan, Newark 1, N. J.

148R

METEOROLOGICAL INSTRUMENTS

Leupold & Stevens Inst., 4445 N. E. Glisaen, Portland, Ore.
Payne Dean and Co., Madison, Conn.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Wallace and Tiernan, Newark 1, N. J.

149R

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.

Alabama Pipe Co., Box 791, Anniston, Ala.
Badger Meter Mfg. Co., 2371 N. 30th St., Milwaukee 45, Wis.
Art Concrete Works, 366 S. Fair Oaks Ave., Pasadena, Calif.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201 N. Talman Drive, Chicago, Ill.
Kennedy Valve Mfg. Co., E. Water St., Elmira, N. Y.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.
R. D. Wood Co., Public Ledger Bldg., Philadelphia 5, Pa.

150R

METER CLEANING (Equipment and Chemicals)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
W. S. Darley & Co., 2810 Washington St., Chicago 12, Ill.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Neptune Meter Co., 50 West 50th Street, New York 20, New York.

151R

METER COUPLINGS & YOKES

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.
Worthington-Gamon Meter Division, Worthington Corp., 296 South St., Newark, N. J.

152R

METER REPAIR PARTS

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 West 50th St., New York 20, N. Y.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
Worthington-Gamon Meter Div., Worthington Corp., 296 South St., Newark 5, N. J.

153R

METERS, ELECTRIC

Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
General Electric Co., 1 River Road, Schenectady, N. Y.
Infilco Inc., 325 25th Pl., Chicago 16, Ill.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

154R

METERS, FLOW TUBE

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 345 Harris Ave., Providence 1, R.I.
Fischer & Porter Co., 925 Warminister Rd., Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

155R

METERS, GAS

Bailey Meter Company, 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 345 Harris Ave., Providence 1, R.I.
Fischer & Porter Co., Hatboro, Pa.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roots-Connersville Blower Div., Dresser Industries, Inc., 900 W. Mount St., Connersville, Ind.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia 42, Pa.

156R

METERS (Turbine Type)

Badger Meter Mfg. Co., 2371 N. 30th St., Milwaukee 45, Wis.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Hersey Mfg. Co., So. Boston 27, Mass.
Neptune Meter Co., 50 W. 50th St., New York 20, N. Y.
Sparling Meter Co., Box 3277 Los Angeles 54, Calif.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Worthington-Gamon Meter Div., Worthington Corp., 296 South St., Newark 5, N. J.

157R

METER TESTING EQUPMENT

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 W. 50th St., New York City.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Worthington-Gamon Meter Co., Newark, N. J.

158R

METERS, VENTURI

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

159R

METERS, WATER (Consumer)

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Buffalo Meter Co., 2917 Main St., Buffalo, N. Y.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 West 50th St., New York 20, N. Y.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Worthington-Gamon Meter Division, Worthington Corp., 296 South St., Newark, N. J.

160R

MIXERS AND MIXING EQUIPMENT
(Chemical, Water and Sewage)

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., Colmar, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equipment, Inc., P. O. Box 266, Aurora, Ill.
Worthington Corp., Harrison, N. J.

161R

MOTORS, ELECTRIC

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Electric Mach. Mfg. Co., 800 Central Ave., Minneapolis 13, Minn.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., 1 River Road, Schenectady, N. Y.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kansas.
U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

162R

NOZZLES, FLOW

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

163R

NOZZLES, SPRAY (Water and Sewage)

Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., Colmar, Pa.
Minneapolis Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.

164R

OIL (Cutting and Threading)

Grinnell Co., 260 W. Exchange St., Providence 1, R. I.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.

165R

OPERATING TABLES (Filter)

Amer. Water Softener Co., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Filtration Equip. Corp., 271 Hollenbeck St., Rochester 21, N. Y.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

166R

ORIFICES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

167R

OZONE EQUIPMENT

The Welsbach Corp., Ozone Processes Div., 1500 Walnut St., Philadelphia 2, Pa.

168R

PACKING (Pumps and Valves)

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Johns-Manville, 22 E. 40th St., New York 16, N. Y.
Keasbey & Mattison Co., Ambler, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.
Smith-Blair, Inc., 535 Railroad Ave., So. San Francisco, Calif.

169R

PAINT (Acid Resisting)

Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.
Atlas Mineral Prod. Co., Mertztown, Pa.
Heresite & Chemical Co., Manitowoc, Wis.
Koppers Company, Inc., 1301 Koppers Bldg., Pittsburgh 19, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

170R

PENSTOCKS

American Locomotive Co., Schenectady, N. Y.
Bethlehem Steel Co., Bethlehem, Pa.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.

171R

pH TEST EQUIPMENT

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Beckman Instruments, Inc., So. Pasadena 1, Calif.
Foxboro Co., Neponset Ave., Foxboro, Mass.
General Laboratory Supply Co., P. O. Box 2607, Paterson, N. J.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
The Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan, 25 Main St., Belleville, N. J.

172R

PHOTOELECTRIC COLORIMETERS

Beckman Instruments, Inc., So. Pasadena 1, Calif.
General Laboratory Supply Co., P. O. Box 2607, Paterson, N. J.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia, 44, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond 5, Va.
Wilkens-Anderson Co., 4525 W. Division St., Chicago 57, Ill.

173R

PIPE & FITTINGS, LINED

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Heresite & Chemical Co., Manitowoc, Wis.
McWane Cast Iron Pipe Co., Box 2601, Birmingham 2, Ala.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., 3300 First Ave. North, Birmingham, Ala.

174R

PIPE AND TANK COATINGS

Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.
Atlas Mineral Products Co., Mertztown, Pa.
Heresite & Chemical Co., Manitowoc, Wis.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Koppers Co., Inc., 1301 Koppers Bldg., Pittsburgh 19, Pa.

175R

PIPE, ASBESTOS-CEMENT

Corey Mfgr. Co., 3279 Verdugo Rd., Los Angeles 65, Calif.
Heresite & Chemical Co., Manitowoc, Wis.
Johns-Manville Co., 22 E. 40th St., New York 16, N. Y.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Keasbey & Mattison Co., Ambler, Pa.

176R

PIPE BENDING MACHINES
(Hydraulic & Mechanical)

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Greenlee Tool Co., 2136 12th St., Rockford, Ill.
Jos. G. Pollard Co., Inc., 141 S. Ashland Pl., Brooklyn 1, N. Y.
M. B. Skinner Co., Sample St., South Bend, Ind.

177R

PIPE, CAST IRON

Alabama Pipe Co., Box 791 Anniston, Ala.
American Cast Iron Pipe Co., 2930 N. 16th St., Birmingham 2, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
James B. Clow & Sons, 201-299 No. Talman Ave., Chicago 12, Ill.
Combustion Engineering, Inc., 200 Madison Ave., New York 16, N. Y.
Corey Mfgr. Co., 3279 Verdugo Rd., Los Angeles 65, Calif.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
McWane Cast Iron Pipe Co., P.O. Box 2601, Birmingham, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., 3300 First Ave. North, Birmingham 2, Ala.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

178R

PIPE, CEMENT LINED

Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
American Cast Iron Pipe Co., 2930 N. 16th St., Birmingham 2, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
McWane Cast Iron Pipe Co., P. O. Box 2601, Birmingham 2, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., 3300 First Ave. North, Birmingham 2, Ala.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

179R

PIPE, CEMENT LINING OF

Centriline Corp., 140 Cedar St., New York 6, N. Y.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
McWane Cast Iron Pipe Co., Box 2601 Birmingham 2, Ala.
Pipe Linings, Inc., 4675 Firestone Blvd., South Gate, Calif.
United States Pipe and Foundry Co., Burlington, N. J.

180R

PIPE, CONCRETE, PRESSURE

American Concrete Pressure Pipe Assn, 228 N. LaSalle St., Chicago 1, Ill.
Cement Gun Co., Inc., 1520 Walnut St., Allentown, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Price Bros. Co., 1932 E. Monument Ave., Dayton 1, Ohio.

181R

PIPE, COPPER, BRASS AND BRONZE

The American Brass Co., 414 Meadow St., Waterbury 20, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Mueller Co., 512 Cerro Gordo St., Decatur, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

182R

PIPE, CULVERT

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Continental Steel Corp., 1109 S. Main St., Kokomo, Ind.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, New York.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l. Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago, Ill.
Price Bros. Co., P. O. Box 825, Dayton 1, Ohio.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
United States Pipe and Foundry Co., 3300 First Ave. North, Birmingham 2, Ala.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.

R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

183R

PIPE CUTTING MACHINES

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Ellis & Ford Mfg. Co., Inc., 2423 Goodrich Ave., Ferndale 20, Mich.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Jos. G. Pollard Co., Inc., New Hyde Park, N. Y.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

184R

PIPE DRILLS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Mueller Co., Decatur 70, Ill.
Jos. G. Pollard Co., Inc., 141 Ashland Pl., Brooklyn 1, N. Y.
The A. P. Smith Mfg. Co., East Orange, N. J.

185R

PIPE ENAMELS, PROTECTIVE—COAL TAR

American Locomotive Co., Schenectady, N. Y.
Koppers Company, Inc., 1301 Koppers Bldg., Pittsburgh 19, Pa.

PIPE FITTINGS (See Fittings)

PIPE, HARD RUBBER LINED
(See Rubber Lined Pipe & Valves)

PIPE JOINT COMPOUNDS
(See Jointing Compounds)

186R

PIPE JOINT PACKING,

Atlas Mineral Products Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Northrop & Company, Inc., Spring Valley, N. Y.
Presstite Engr. Co., 3738 Choutau Ave., St. Louis 10, Mo.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

187R

PIPE JOINTS (Mechanical)

Alabama Pipe Co., Box 791, Anniston, Ala.
H. Y. Carson Co., 1221 Pinson St., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
James B. Clow & Sons, 201-209 N. Talman Ave., Chicago 80, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
McWane Cast Iron Pipe Co., P. O. Box 2601, Birmingham 2, Ala.
United States Pipe and Foundry Co., 3300 First Ave. North, Birmingham 2, Ala.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

188R

PIPE JOINT TOOLS

Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., New Hyde Park, N. Y.

189R

PIPE LOCATORS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Detectron Corp., 5420 Vineland Ave., No. Hollywood, Calif.
Filtration Equip Corp., 271 Hollenbeck St., Rochester 21, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
Wilkinson Products Co., 2987 Chevy Chase Drive, Pasadena 8, Calif.

190R

PIPE, PLASTIC

Atlas Mineral Products Co., Mertztown, Pa.
Carlon Products Corp., 10300 Meech Ave., Cleveland, Ohio.
Continental Can Co., Mills Plastic Pipe Div., 100 E. 42nd St., New York 17, N. Y.
Kraloy Plastic Pipe Co., Inc., 4710-20 E. Washington Blvd., Los Angeles 22, Calif.
Phipps & Byrd, Inc., 6th & Byrd Sts., Richmond, Va.
Yardley Plastics Co., 142 Parsons Ave., Columbus 15, O.

191R

PIPE, PUSHERS (Hydraulic)

W. S. Darley & Co., 2810 Washington St., Chicago 10, Ill.
Greenlee Tool Co., 2136 12th St., Rockford, Ill.

192R

PIPE, SEWER

Bethlehem Steel Co., Bethlehem, Pa.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Johns-Manville, 22 E. 40th St., New York 16, N. Y.
Keasbey & Mattison Co., Ambler, Pa.
Kraloy Plastic Pipe Co., 4720 E. Washington Blvd., Los Angeles, Calif.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l. Clay Pipe Mfrs., 100 N. La Salle St., Chicago, Ill.
Price Bros. Co., 1932 E. Monument Ave., Dayton 1, Ohio.
U. S. Pipe & Foundry Co., 3300 First Ave. North, Birmingham 2, Ala.

193R

PIPE, STEEL (All Types)

American Locomotive Co., Schenectady, N. Y.
Bethlehem Steel Co., Bethlehem, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
The National Supply Co., P. O. Box 416, Pittsburgh 30, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 15, Kan.

194R

PIPE TAPPING MACHINES

Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

195R

PIPE TEST PLUGS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Flexible Sewer Rod Equip. Co., 9059 Venice Blvd., Los Angeles, Calif.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

196R

PIPE THAWING, ELECTRICAL, STEAM, FLAME

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Joseph G. Pollard Co., New Hyde Park, N. Y.

197R

PIPE TOOLS,
(Asbestos, Cement)

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Keasbey & Mattison Co., Ambler, Pa.
Johns-Manville, 22 E. 40th St., New York 16, N. Y.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
Ridge Tool Co., 400 Clark St., Elyria, Ohio

198R

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Marlow Pumps, Ridgewood, N. J.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

PIPE, VITRIFIED CLAY
(See Vitrified Clay Pipe and Products.)

199R

PIPE WRAPPING

Johns-Manville Corp., 22 East 40th St., New York 16, N. Y.

200R

PIPE, WROUGHT IRON

A. M. Byers Co., Clark Bldg., Pittsburgh 22, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 N. Exchange St., Providence 1, R. I.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Sonken-Galamba, 2nd & Riverview, Kansas City 18, Kan.

201R

PITOT TUBES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Leupold & Stevens Inst., 4445 N. E. Glissen, Portland, Ore.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

PLASTIC PIPE & TUBING
(See Pipe Plastic)

PNEUMATIC CONVEYORS
(See Conveyors & Conveying Equip.)

202R

POROUS TUBES AND PLATES

American Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
Filtros, Inc., East Rochester, N. Y.
Norton Co., New Bond St., Worchester 6, Mass.
Walker Process Equipment, Inc., 840 N. Russell Ave., Aurora, Ill.

203R

POWER TAKE-OFFS
(Truck Type)

Payne Dean Co., Madison, Conn.

PRESSURE REGULATORS
(See Regulators, Pressure)

204R

PRESTRESSED CONCRETE TANKS

Cement Gun Co., Inc., 1520 Walnut St., Allentown, Pa.

PROPORTIONING EQUIPMENT
(See Chemical Feed and Proportioning Equip.)

205R

PUMPING CONTROLS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Fischer & Porter Co., 925 Warminister Rd., Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Healy-Ruff Co., 2255 University Ave., St. Paul 14, Minn.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kans.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.

206R

PUMP PRIMERS

Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
Marlow Pumps, Box 566, Ridgewood, N. J.

207R

PUMPS, ACID-HANDLING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Economy Pumps, Inc., 19th & Lehigh, Philadelphia 32, Pa.
Hills-McCanna Co., 2357 W. Nelson St., Chicago 18, Ill.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.
Manzel, Inc., 244 Babcock St., Buffalo, N. Y.
Peerless Pump Div., Food Machy. & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Calif.
Precision Machine Co., 8 Walnut St., Somerville 43, Mass.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace & Tiernan, Inc., 25 Main St., Belleville, N. J.
Worthington Corp., Harrison, N. J.

PUMPS, CELLAR DRAINER
(See Pumps, Sump)

208R

PUMPS, CENTRIFUGAL

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wisc.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Economy Pumps, Inc., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Homelite Corp., Port Chester, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Marlow Pumps, Box 566, Ridgewood, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Div., Food Machy. & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Calif.
Phipps & Bird, Inc., 6th & Byrd Sts., Richmond, Va.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Corp., Harrison, N. J.

209R

PUMPS, DEEP WELL

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.
Layne & Bowler, Inc., Box 6697, Hollywood Sta., Memphis 8, Tenn.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Peerless Pump Div., Food Machy. & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Corp., Harrison, N. J.

210R

PUMPS, DIAPHRAGM

Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wisc.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tuscon, Ariz.
Komline-Sanderson Engr. Corp., Peapack, N.J.
Marlow Pumps Inc., Box 566, Ridgewood, N. J.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Joseph G. Pollard Co., New Hyde Park, N. Y.
Precision Machine Co., 8 Walnut St., Somerville 43, Mass.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
W. S. Rockwell Co., 2764 Eliot St., Fairfield, Conn.
Wallace & Tiernan, Inc., 25 Main St., Belleville, N. J.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

211R

PUMPS, HYDRANT

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

212R

PUMPS, HYDRAULIC (Pressure Boosting)

De Laval Steam Turbine Co., Trenton 2, N.J.
Ross Valve Mfg. Co., Inc., 4 Oakwood Ave., Troy, N. Y.

213R

PUMPS, PORTABLE

Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 4, Wisc.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Deming Co., Salem, Ohio.
Fairbanks Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Port Chester, N. Y.
Komline-Sanderson Engr. Corp., Peapack, N. J.
Manzel, Inc., 244 Babcock St., Buffalo, N. Y.
Marlow Pumps, Box 566, Ridgewood, N. J.
Peerless Pump Div., Food Machy. & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Calif.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Worthington Corp., Harrison, N. J.

214R

PUMPS, ROTARY

Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Komline-Sanderson Engr. Corp., Peapack, N.J.
Manzel, Inc., 244 Babcock St., Buffalo, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa.
Roots-Connersville Blower Div., Dresser Industries, Inc., 900 W. Mount St., Connersville, Ind.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Corp., Harrison, N. J.

215R

PUMPS, SELF PRIMING

Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wisc.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
W. S. Darley & Co., 2810 Washington Blv., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., P. O. Box 215 Hollywood Sta., Memphis 8, Tenn.
Manzel, Inc., 244 Babcock St., Buffalo, N. Y.
Marlow Pumps, Box 566, Ridgewood, N. J.
Peerless Pump Div., Food Machy. & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Calif.
Worthington Corp., Harrison, N. J.

216R

PUMPS, SEWAGE AND DRAINAGE

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Dorr Co., Barry Place, Stamford, Conn.
Economy Pumps, Inc., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Homelite Corp., Port Chester, N. Y.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.
Marlow Pumps, Box 566, Ridgewood, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Div., Food Machy. & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Calif.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Corp., Harrison, N. J.

217R

PUMPS, SLUDGE

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Dorr Co., Barry Place, Stamford, Conn.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Komline-Sanderson Engr. Corp., Peapack, N. J.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa.
Marlow Pumps, Box 566, Ridgewood, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Div., Food Machy. & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Calif.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Worthington Corp., Harrison, N. J.

218R

PUMPS, SUMP (AND CELLAR DRAINER)

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St. Aurora, Ill.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Deming Co., Salem, Ohio.
Dorr Co., Barry Place, Stamford, Conn.
Economy Pumps, Inc., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Homelite Corporation, Port Chester, New York.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.
Marlow Pumps, Box 566, Ridgewood, N. J.
A. Y. McDonald Mf., Co., 12th Pine Sts., Dubuque, Iowa.
Peerless Pump Div., Food Machy. & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Calif.
Worthington Corp., Harrison, N. J.

219R

PUMPS, TURBINE

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
De Laval Steam Turbine Co., Nottingham Way, Tranton 2, N. J.
Deming Co., Salem, Ohio.
Economy Pumps, Inc., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.
Layne & Bowler, Inc., Box 6697 Hollywood Sta., Memphis 8, Tennessee.
Peerless Pump Div., Food Machy. & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Calif.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Worthington Corp., Harrison, N. J.

220R

PUMPS, VACUUM

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Roots-Connersville Blower Div., Dresser Industries, Inc., 900 W. Mount St., Connersville, Ind.
Worthington Corp., Harrison, N. J.

RAIN GAGES (See Meteorological Instruments)

221R

RATE OF FLOW CONTROLLERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Bulkley Dunton Processes, Inc., 295 Madison Ave., New York 17, N. Y.
Fischer & Porter Company, 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul 4, Minnesota.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Insts., Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 6th & Byrd Sts., Richmond, Va.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

222R

RATE OF FLOW RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Phipps & Bird, Inc., 6th & Byrd Sts., Richmond, Va.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
S. Morgan Smith Co., York, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

223R

REAMERS

Mueller Co., Decatur 70, Ill.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.

RECARBONATORS

(See Carbonators)

224R

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York 16, N. Y.
Norton Co., New Bond St., Worchester 6, Mass.

225R

REGULATORS, PRESSURE (Water and Gas)

American Radiator Co., Bessemer Bldg., Pittsburg, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh.
Healy-Ruff Co., 2255 University Ave., St. Paul 4, Minnesota.
Manzel Div., Frontier Industries, 315 Babcock St., Buffalo 10, N.Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Rockwell Manufacturing Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

RESERVOIRS, STEEL (See Tanks & Standpipes)

226R

RESIDUAL CHLORINE CONTROLLERS

Wallace & Tiernan Co., Inc., 25 Main St., Belleville, N. J.

227R

RESIDUAL CHLORINE TEST APPARATUS

Builders-Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
Phipps & Bird, Inc., 6th & Byrd Sts., Richmond, Va.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan, Inc., 25 Main St., Belleville, N. J.

228R

ROOF COATINGS

Johns-Manville Corp., 22 East 40th St., New York 16, New York.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Presstite Engr. Co., 3738 Chouteau Ave., St. Louis 10, Mo.

229R

RUBBER LINED PIPE AND VALVES

Darling Valve & Mfg. Co., Williamsport, Pa.
Heresite & Chemical Co., Manitowoc, Wis.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.

230R

RUBBER PACKING GASKETS

Atlas Mineral Products Co., Mertztown, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Il.
Johns-Manville Corp., 22 East 40th St., New York 16, New York.
Northrop & Co., Spring Valley, N. Y.
Smith-Blair, Inc., 535 Railroad Ave., So. San Francisco, Calif.

231R

RUST PREVENTION (Water Treatment)

Calgon, Inc., Hagan Bldg., 323 4th Ave., Pittsburgh, Pa.
Electro Rust-Proofing Corp., 30 Main St., Belleville 9, N. J.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Solvay Process Div., Allied Chemical & Dye Corp., 61 Broadway, New York 6, N. Y.

232R

SADDLES, PIPE

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington St., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Brandford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Kraloy Plastic Pipe Co., Inc., 4710-20 E. Washington Blvd., Los Angeles 22, Calif.
Mueller Co., Decatur 70, Ill.
Price Bros. Co., 1932 E. Monument Ave., Dayton 1, Ohio.
M. B. Skinner Co., Sample St., South Bend, Ind.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

233R

SAMPLERS AND SAMPLING TABLES

Builders-Providence, Inc., 345 Harris Ave., Providence 1, R.I.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
Hardinge Co., Inc., 240 Arch St., York, Pa.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Phipps & Bird, Sixth & Byrd Sts., Richmond, Va.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

234R

SAND EXPANSION INDICATORS

Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Infilco, Inc., Tucson, Ariz.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

235R

SCALES, SLUDGE CONVEYOR

Builders-Providence., Inc.,350 Harris Ave., Providence 1, R. I.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.

236R

SCALES, WEIGHING

Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Wallace & Tiernan, Inc., 25 Main St., Belleville 9, N. J.

SCREENING AND COMMINUTING (See Comminuting Devices)

SCREENINGS GRINDERS

(See Grinders)

237R

SCREENS, INTAKE

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wisc.
Rodney Hunt Machine Co., 84 Lake St., Orange, Mass.
Link-Belt Co., Colmar, Pa.
Newport News Shipbuilding & Dry Dock Co., Newport News, Va.

238R

SCREENS, SEWAGE

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wisc.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Rodney Hunt Machine Co., 84 Lake St., Orange, Mass.
Infilco, Inc., Tucson, Ariz.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Newport News Shipbuilding & Dry Dock Co., Newport News, Va.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Walker Process Equip. Co., 840 N. Russell Ave., Aurora, Ill.

239R

SCREENS, VIBRATING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Gruendler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Separator Div., Southwestern Engr. Co., 4800 Santa Fe Ave., Los Angeles 58, Calif.

240R

SCREEN, WATER WELL

Layne & Bowler, Inc., Box 6697, Hollywood Sta., Memphis 8, Tennessee.

SCUM REMOVERS

(See Clarifiers.)

241R

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)

Infilco, Inc., Tuscon, Ariz.
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.

242R

SERVICE BOXES (Water)

Alabama Pipe Co., Box 791, Anniston, Ala.
Art Concrete Works, 366 S. Fair Oaks Ave., Pasadena, Calif.
James B. Clow & Sons., 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

SEWAGE EJECTORS

(See Ejectors, Pneumatic.)

243R

SEWAGE SAMPLERS

Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

SEWAGE SLUDGE DRYERS

(See Drying Systems, Sludge)

SEWAGE SLUDGE INCINERATOR

(See Incinerators)

244R

SEWER CLEANING EQUIP. AND SERVICE

Bucyrus-Erie Co., South Milwaukee, Wis.
Champion Corp., 4714 Sheffield Ave., Hammond, Ind.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Smith & Loveless Inc., 62nd & Merriam Dr., Merriam, Kansas.

SEWER PIPE

(See Pipe, Sewer.)

245R

SEWER PIPE JOINTS (and Jointing Compounds)

Atlas Mineral Prod. Co., Mertztown, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
National Clay Pipe Manufacturers, Inc., 100 North LaSalle St., Chicago 2, Illinois.
Northrop & Company, Inc., Spring Valley, N. Y.
Presstite Engr. Co., 3738 Chouteau Ave., St. Louis 10, Mo.

246R

SEWER RODS

Champion Corp., 4714 Sheffield Ave., Hammond, Ind.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

247R

SIPHONS (Sewage Dosing)

American Well Works, 100 N. Broadway, Aurora, Ill.
H. D. Fowler Co., Inc., 901 Lane St., (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kansas.

248R

SLEEVES, PIPE REPAIR

Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Corey Mfg. Co., 3279 Verdugo Rd., Los Angeles 65, Calif.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
M & H Valve & Fitting Co., Box 909, Anmiston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur, Ill.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

249R

SLEEVES, TAPPING (Valve)

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Eddy Valve Co., Waterford, N. Y.
Darling Valve & Manufacturing Co., Williamsport, Penna.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Rennselaer Valve Co., Ontario Street, Troy, New York.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.

250R

SLUDGE COLLECTORS

American Well Works, 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes, Inc., 295 Madison Ave., New York 17, N. Y.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wisc.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

251R

SLUDGE DISINTEGRATORS

Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Gruendler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE DRYERS

(See Drying Systems)

SLUDGE EJECTORS

(See Ejectors, Pneumatic.)

SLUDGE GAS ENGINES

(See Engines, Sludge Gas)

SLUDGE INCINERATORS

(See Incinerators)

SLUDGE PUMPS

(See Pumps, Sludge)

252R

SLUDGE SAMPLERS

Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
General Laboratory Supply Co., P. O. Box 2607, Paterson, N. J.
Infilco, Inc., Tucson, Ariz.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

253R

SLUDGE VALVES (Telescopic)

American Car & Foundry Co., Valve Div., 30 Church St., New York, N. Y.
American Well Works, 100 N. Broadway, Aurora, Ill.
Homestead Valve Mfg. Co., Box 42, Coraopils, Pa.
Link Belt Co., Colmar, Pa.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.

254R

SODA ASH

Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Maryland.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Solvay Process Div., Allied Chemical & Dye Corporation, 61 Broadway, New York 6, N. Y.

255R

SODIUM BISULPHITE

Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

256R

SODIUM CHLORITE

Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Maryland.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

257R

SODIUM HYPOCHLORITE

John Wiley Jones Co., 100 Sunny Sol Blvd., Caledonia, N. Y.
Wallace & Tiernan, Inc., 25 Main St., Belleville, N. J.

258R

SODIUM PHOSPHATES (Glassy)

Calgon, Inc., Hagan Bldg., 323 Fourth Ave., Pittsburgh 22, Pa.
Phipps & Bird, 303 S. Sixth St., Richmond, Va.

259R

SODIUM SILICATE

Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Phipps & Bird, 303 S. Sixth St., Richmond, Va.

SOFTENERS

(See Water Softening Equipment)

260R

SPEED REDUCERS, TRANSMISSION

De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link Belt Co., Colmar, Pa.
U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.
Worthington Corp, Harrison, N. J.

SPRINKLING FILTER EQUIP.

(See Trickling Filter Equip.)

SPRINKLING FILTER UNDERDRAINS

(See Filter Underdrains, Sewage.)

261R

STACKS

(Steel and Wrought Iron)
Bethlehem Steel Co., Bethlehem, Pa.
A. M. Byers Co., Box 1076, Pittsburgh, Pa.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.

STANDPIPES

(See Tanks and Standpipes.)

262R

STIRRERS (Laboratory)

General Laboratory Supply Co., P. O. Box 2607, Paterson, N. J.
Omega Machine Co., 345 Harris Avenue, Providence 1, Rhode Island.
Phipps & Bird, Inc., 303 S. 6th St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

263R

STOKERS

Combustion Engineering, Inc., 200 Madison Ave., New York, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Link-Belt Co., Colmar, Pa.
Westinghouse Electric & Mfg. Co., Pittsburgh 30, Pa.

264R

STRAINERS, SUCTION

Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
R.-S. Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.

SULPHATE OF ALUMINA

(See Filter Alum)

265R

SULPHUR DIOXIDE (Liquid)

Tennessee Corp., 617-29 Grant Bldg., Atlanta 1, Ga.

266R

SWITCHBOARD & SWITCH GEAR

Electric Mach. Mfg. Co., 800 Central Ave., Minneapolis 13, Minn.
General Electric Co., 1 River Road, Schnectady, N. Y.
Westinghouse Electric Mfg. Co., Pittsburgh 30, Pa.

267R

TANK LININGS

Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.
Cement Gun Co., Inc., 1520 Walnut St., Allentown, Pa.
Heresite & Chemical Co., Manitowoc, Wis.

268R

TANK MAINTENANCE & REPAIR

Cement Gun Co., Inc., 1520 Walnut Street, Allentown, Penna.
Dixie Tank & Bridge Co., P. O. Box 14, Memphis 1, Tenn.
R. D. Cole Mfg. Co., Newnan, Ga.
Electro Rust Proofing Corp., 30 Main St., Belleville 9, N. J.
Koppers Co., 1301 Koppers Bldg., Pittsburgh 19, Pa.
Speelmon Elevated Tank Service, 822 N. Court St., Rockford, Ill.

269R

TANKS AND STANDPIPES (Steel)

Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Bethlehem Steel Co., Bethlehem, Pa.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

270R

TANKS, RUBBER LINED

Atlas Mineral Products Co., Mertztown, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
Heresite & Chemical Co., Manitowoc, Wis.
Rodney Hunt Machine Co., 84 Lake St., Orange, Mass.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.

271R

TAPPING MACHINES

Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

272R

TASTE & ODOR REMOVAL CHEMICALS

Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York 17, N. Y.
Mathieson Industrial Chemical Co., Baltimore 3, Maryland.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Welsbach Corp., Ozone Processes Division, 1500 Walnut Street, Philadelphia 2, Pa.

273R

TESTERS (Water Meter)

Badger Meter Mfg. Co. 2371 N. 30th St., Milwaukee 45, Wisc.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 W. 50th St., New York City.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Worthington-Gamon Meter Co., Newark, N. J.

274R

THICKENERS (Sludge)

Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 4610 W. Greenfield Ave., Milwaukee 1, Wisc.
Dorr Co., Barry Place, Stamford, Conn.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 947 N. Fourth Ave., Columbus 16, Ohio.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Link Belt Co., Colmar, Pa.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

TOOLS, PIPE

(See Pipe Tools)

275R

TOOLS, PNEUMATIC

Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Worthington Corp., Harrison, N. J.

276R

TRACTORS, BULLDOZERS, Etc.

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Bucyrus-Erie Co., South Milwaukee, Wis.
Oliver Corp., 400 W. Madison St., Chicago 6, Ill.

277R

TRANSFORMERS, ELECTRIC

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Westinghouse Electric Corp., Pittsburgh, Pa.

278R

TRAPS, DRIP, FLAME, SEDIMENT, STEAM

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.

H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Neptune Meter Co., 50 W. 50th St., New York 20, N. Y.
Pacific Flush Tank Co., 4341 Ravenswood Ave., Chicago 13, Ill.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.

279R

TRENCHING EQUIPMENT

Bucyrus-Erie Co., South Milwaukee, Wis.
Oliver Corp., 400 W. Madison St., Chicago 6, Il.

280R

TRICKLING FILTER EQUIPMENT

American Well Wks., 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Avenue, Chicago 13, Illinois.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Smith & Loveless, 62nd & Merriam Dr., Merriam, Kansas.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.

TRICKLING FILTER UNDERDRAINS

(See Filter Underdrains)

281R

TURBIDIMETERS

General Electric Co., 1 River Road, Schenectady 5, N. Y.
General Laboratory Supply Co., P. O. Box 2607, Paterson, N. J.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44,
Phippe & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

282R

TURBINES, HYDRAULIC

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Pelton Water Wheel Co., 2929 19th St., San Francisco 10, Calif.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.

283R

TURBINES, STEAM

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison, N. J.

284R

VACUUM FILTERS

Komline-Sanderson Engr. Corp., Peapack, N. J.
Process Engineers, Inc., 420 Peninsular Ave., San Mateo, Calif.

285R

VALVE BOXES

Alabama Pipe Co., Box 791, Anniston, Ala.
Art Concrete Works, 366 S. Fair Oaks Ave., Pasadena, Calif.
Chapman Valve Mfg., Indian Orchard, Mass.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

286R

VALVE BOX LOCATORS

Aqua Survey & Instrument Co., 2518 Leslie Ave., Cincinnati 12, Ohio.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Detectron Corp., 5420 Vineland Ave., No. Hollywood, Calif.
Joseph G. Pollard Co., New Hyde Park, N. Y.
Wilkinson Products Co., 3987 Chevy Chase Dr., Pasadena 3, Calif.

287R

VALVE INSERTING MACHINES

Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

VALVE OPERATOR

(See Gate Valve Operator)

288R

VALVE VAULT COVERS

E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

289R

VALVES, AIR RELEASE & VACUUM BREAKING

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N.Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Iowa Valve Co., 201 N. Talman Ave., Chicago, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Inc., P. O. Box 388, Troy, N. Y.
Pelton Water Wheel Co., 2929 19th St., San Francisco 10, Calif.
Rockwell Mfg. Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

290R

VALVES, ALTITUDE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.

291R

VALVES, BUTTERFLY

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wisc.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Crane Co., 836 S. Mich. Ave., Chicago 5, Ill.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Pelton Water Wheel Co., 2929 19th St., San Francisco, Calif.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
R-S. Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.

292R

VALVES, CHECK

Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hersey Mfg. Co., South Boston 27, Mass.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.

293R

VALVES, CHLORINE

Amer. Car and Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.
Wallace and Tiernan, Newark 1, New Jersey.

294R

VALVES, CONE

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Homestead Valve Mfg. Co., Box 42, Coraopolis, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.

295R

VALVES, DIAPHRAGM

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

VALVES, ELECTRICALLY OPERATED

(See Valves, Motor Operated.)

296R

VALVES, FLAP

Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Rodney Hunt Machine Co., 84 Lake St., Orange, Mass.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

297R

VALVES, FLOAT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.

Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine St., Dubuque, Iowa.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.

298R

VALVES, FOOT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Eddy Valve Co., Waterford, N. Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine St., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

299R

VALVES, FOUR WAY

American Water Softener Co., Philadelphia 33, Pa.
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Homestead Valve Mfg. Co., Box 42, Coraopolis, Pa.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Rockwell Manufacturing Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

300R

VALVES, GATE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine St., Dubuque, Iowa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
R-S Products Corp, 4600 Germantown Ave., Philadelphia 44, Pa.

301R

VALVES, HYDRAULIC CYLINDER OPERATED

Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 East Becher St., Milwaukee 7, Wis.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Homestead Valve Mfg. Co., Box 42, Coraopolis, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
Rensselaer Valve Company, Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

302R

VALVES, LUBRICATED PLUG

American Car and Foundry Co., Valve Division, 1501 Ferry Avenue East, Detroit, Michigan.
Homestead Valve Mfg. Co., Box 42, Coraopolis, Pa.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
W. S. Rockwell Co., 2764 Eliot St., Fairfield, Conn.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
R-S Products Corp, 4600 Germantown Ave., Philadelphia 44, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

303R

VALVES MECHANICAL JOINT

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Iowa Valve Co., 201 N. Talman St., Chicago, Ill.
The Kennedy Valve Mfg. Co., E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M & H Valve & Fitting Co., Anniston, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.
R. D. Wood Co., Public Ledger Bldg., Philadelphia 5, Pa.

304R

VALVES, MOTOR OPERATED

American Car & Fdy. Co., Valve Div., 1501 E. Ferry Ave., Detroit 11, Mich.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Homestead Valve Mfg. Co., Box 42, Coraopolis, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Payne Dean and Co., Madison, Conn.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

305R

VALVES, MUD AND PLUG

American Car & Fdy. Co., Valve Div., 1501 E. Ferry Ave., Detroit 11, Mich.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Homestead Valve Mfg. Co., Box 42, Coraopolis, Pa.
Rodney Hunt Machine Co., 84 Lake St., Orange, Mass.
Infilco, Inc., Tucson, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
Rockwell Mfg. Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

306R

VALVES, PRESSURE REDUCING

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

307R

VALVES, RELIEF

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., N. Y. 20.
Pelton Water Wheel Co., 2929 19th St., San Francisco 10, Calif.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp, 4600 Germantown Ave., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia 42, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas.
Weisbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

308R

VALVES (Rubber, Plastic, Glass or Lead)

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Mfg. Co., Williamsport, Penna.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
W. S. Rockwell Co., 2764 Eliot St., Fairfield, Conn.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith, York, Pa.

309R

VALVES, SPECIAL, AUTOMATIC (Including Remote Control.)

American Car & Fdy., Valve Div., 1501 E. Ferry Ave., Detroit 11, Mich.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Northside, Pittsburgh 33, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1936 E. Water St., Elmira, N. Y.
M & H Valve & Fitting Co., Box 909, Anniston, Ala.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
A. P. Smith Mfg. Co., 595 N. Arlington Ave., E. Orange, N. J.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

310R

VALVES, WATER METER SPECIAL

Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., South Boston 27, Mass.
Kennedy Valve Mfg. Co., E. Water St., Elmira, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

311R

VARIABLE SPEED TRANSMISSIONS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Electric Machinery Mfg. Co., 800 Central Ave., Minneapolis 13, Minn.
Link Belt Co., Colmar, Pa.
U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.
Worthington Corp., Harrison, N. J.

312R

VENTURI TUBES

American Water Softener Co., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

313R

VIBRATING SCREENS (Liquid)

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link Belt Co., Colmar, Pa.

314R

VISES, PIPE

H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
The Ridge Tool Co., 400 Clark Street, Elyria, Ohio.

315R

VITRIFIED CLAY PIPE AND PRODUCTS

Nat'l. Clay Pipe Mfrs., Inc., 100 N. La Salle St., Chicago 2, Ill.

316R

WASTE GAS BURNERS

H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

WATER ANALYSIS EQUIPMENT AND REAGENTS

(See Laboratory Apparatus and Reagents)

317R

WATER HAMMER ARRESTERS

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Pelton Water Wheel Co., 2929 19th St., San Francisco 10, Calif.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

318R

WATER LEAK, LOCATING INSTRUMENTS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Detectron Corp., 5420 Vineland Ave., No. Hollywood, Calif.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Joseph H. Pollard Co., Inc., New Hyde Park, N. Y.
Wilkinson Products Co., 3987 Chevy Chase Drive, Pasadena 3, Calif.

319R

WATER LEVEL CONTROL

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Healy-Ruff Co., 2255 University Ave., St. Paul 14, Minn.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan, Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Smith & Loveless, Inc., 62nd & Merriam Dr., Merriam, Kans.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

320R

WATER LEVEL RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.

321R

WATER MAIN CLEANING

Flexible Sewer-Rod Equipment Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York 7, N. Y.
Robinson Pipe Cleaning Corp., Box 300, Canonsburg, Pa.
Southeastern Contracting Co., Box 9068, Birmingham 9, Ala.

322R

WATER MAIN PACKING GASKETS

Atlas Mineral Products Co., Mertztown, Pa.
Johns-Manville Corp., 22 East 40th Street, New York 16, New York.
Northrop & Co., Spring Valley, N. Y.

323R

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS

Atlas Mineral Products Co., Mertztown, Pa.
Johns-Manville, 22 E. 40th St., New York 16, N. Y.
Koppers Company, Inc., 1301 Koppers Bldg., Pittsburgh 19, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Presatite Engr. Co., 3738 Chouteau Ave., St. Louis 10, Mo.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Standard Dry Wall Products, Inc., Box X, New Eagle, Pa.

WATER SOFTENING CHEMICALS AND COMPOUNDS

(See Individual Chemicals for Water Purification and Softening)

324R

WATER SOFTENING EQUIPMENT

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Chain Belt Co., Milwaukee 1, Wis.
Dorr Co., Inc., Barry Place, Stamford, Conn.
Hills McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Koppers Co., Koppers Bldg., Pittsburgh 19, Pa.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Maryland.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Solvay Process Div., Allied Chemical & Dye Corporation, 61 Broadway, New York 6, N. Y.
Walker Process Equip., Inc., 840 N. Russell Ave., Aurora, Ill.
Worthington Corp., Harrison, N. J.

WATER SUPPLY CONTRACTORS

(See Contractors)

325R

WATER TREATMENT FOR SCALE AND CORROSION

Amer. Water Softener Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Calgon, Inc., 323 4th Ave., Hagan Bldg., Pittsburgh 22, Pa.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Precision Machine Co., 8 Walnut St., Somerville 43, Mass.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Worthington Corp., Harrison, N. J.

326R

WEED KILLERS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

327R

WELL CLEANING CHEMICALS

Calgon, Inc., 323 4th Ave., Pittsburgh 22, Pa.
Layne E. Bowler, Inc., Box 6697, Hollywood Sta., Memphis 8, Tenn.

328R

WELLS, COMPLETE

Layne & Bowler, Inc., Box 6697, Hollywood Sta., Memphis 8, Tennessee.
Ranney Method Water Supplies, Inc., P.O. Box 5415, Columbus 19, Ohio

WRAPPING, PIPE

(See Pipe, Wrapping)

329R

WRENCHES, REVERSIBLE RATCHET

Dresser Mfg. Co., 251 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.

330R

WROUGHT IRON

(Pipe, Gates, Bars, Weirs, etc.)

A. M. Byers Co., Clark Bldg., Pittsburgh 22, Pa.

331R

ZEOLITE AND ZEOLITE SOFTENERS

American Water Softener Co., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Worthington Corp., Harrison, N. J.

WATER & SEWAGE WORKS

reference and data edition

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Management Problems Today

By LOUIS R. HOWSON
Partner, Alvord, Burdick, & Howson, Chicago, Ill.

MANAGEMENT in the abstract sense implies control or mastery. As applied to water works, good management is evidenced by the superiority of capacity over requirements, by revenues adequate to provide good service and finance expansion in advance of need, by the equitable apportioning of revenue requirements among those using the service, and by the general satisfaction of the users.

One of the prime attributes of management is timing. Good management anticipates rather than follows needs. Any water works that has not provided for future needs is habitually unable to meet the needs as they mature, whether they be physical or financial.

There are many types of management problems, including:

1. Being alert to the requirements for service, present and future.

2. Interpreting the service requirements in terms of facilities.

3. Assuring that the facilities are available when needed.

4. Carrying forward ordinary operations with economy and satisfaction to the consumers.

5. Anticipating the necessity for replacing property and making the financial arrangements that are required. (It is the author's belief that inasmuch as facilities furnish service, it is property rather than dollars that must be protected by the depreciation reserve.)

6. Raising the funds necessary to provide for the orderly expansion of the property to meet growing needs.

7. Providing revenues adequate to support the property and its services.

The author feels that the greatest single responsibility of management is to assure that its earnings are sufficient to enable it to supply the best service. As the cost of water service in the average American home is less than 1.5 cents a day per capita, the difference in cost between excellent and mediocre water service rarely exceeds a fraction of a cent per capita per day. This responsibility to assure the best service is shared by regulatory commissions.

Coordination of Activities

Good management, therefore, forecasts its requirements for service, formulates a sound, well-distributed construction program, a sound financial policy, economical administration of operations, and the equitable allocation of revenue requirements through the medium of fair rates. All of these functions must be coordinated to effect a unified, interrelated procedure. Each function has its own problems.

Construction Program

The normal American water utility is a growing institution. The population which it serves rose approximately 35 per cent in the decade 1941-50. Water requirements (127 gpcd in 1945) are usually increasing at a rate of 1-2 gpcd per year.

The cost of supplying water works facilities over the past three decades has increased at least 2.5 times as fast as the population. In 1907 the U.S. census report showed the average book cost of water works to be approximately $30 per capita. Forty years later this figure was approximately $75 per capita. Recent cost-of-reproduction estimates of approximately twenty water plants show an average of 195 per cent of the original costs—that is, the cost of reproducing the average water works in 1952 would be approximately $150 per capita.

As all construction of new facilities must take place in the future, provision for financing must likewise be at future costs. The experience obtained from the Civil War, World War I, and World War II indicates that construction costs will never again be as much as 25 per cent below those of 1952. The Engineering News Record Construction Cost Index in October 1952 stood at 588.48 based on 1913=100. Cost-of-reproduction estimates indicate that water works construction reflects approximately 85 per cent of the increase in the general construction cost index.

It is part of good management for every water works, large or small, to have its future water requirements studied and its construction programmed and periodically reviewed for at least a decade in advance. If these precautions are taken, it will be practicable to coordinate construction and financing and thus make both much simpler and more economical. Only by advance study and planning can inadequacies and the accompanying consumer dissatisfaction be avoided.

The development of a well-considered construction program usually accomplishes the following:

1. It provides the funds required for construction when needed and not before. In this way it saves the fixed charges on expenditures which otherwise might be made before they are necessary, and eliminates the inadequacies in service resulting from delays in carrying out large expansion programs.

2. Construction and expenditures are made as uniform as practicable. A small expenditure for construction made each year is preferable to accumulated deficiencies corrected at infrequent intervals.

3. The development of such a program minimizes future obsolescence in that each year's construction, in addition to being designed to serve the immediate needs, is planned to fit in with ultimate requirements.

Financial Policies

Many of the problems of water works management are independent of ownership, whether public or private. Other problems, such as means of financing growth requirements and determining rates for service within and outside the city limits, differ appreciably in publicly and privately owned water plants.

Private water works are ordinarily financed approximately two-thirds by funded debt and one-third by equity money. The rates must be adequate to attract the necessary capital from both sources. Practically all private water companies are under the jurisdiction of public utility commissions that operate under statutes which, in general, prescribe that rates shall be sufficient to yield a fair return upon the fair value of the property. This general rule has in recent years been superseded in some states, including Illinois, by a "cost of money" basis. In applying this basis, the original cost of the property is reduced by the net credit balance in the depreciation reserve, the funded debt is deducted, and the balance is taken as representing the

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equity interest in the property. Upon this equity interest, a rate of return of approximately 10 per cent is considered necessary to attract capital. On this basis, the equity owners get no compensation for the hazard in constructing and operating the two-thirds of the property represented by debt, and the rate base gives no consideration to inflation, the decreased purchasing power of the dollar, the reproduction cost, or the fair value of the property.

The continued application of this procedure, in the author's opinion, will seriously impair the financial credit of the water companies and their ability to provide the facilities which the consumers should have; consequently, the service will deteriorate. The author sees no justification for differentiating between the basis of valuing water works property and other properties with which the water works is competing for its financial requirements. "Fair value" fluctuates with the purchasing value of the dollar whether that dollar be expended in water works or in an office building. Inasmuch as it is a responsibility of management to provide capital for expansion, it follows that it is also its duty to see that earnings are adequate and properly determined in order that continuity of funds is assured.

Municipalities, on the other hand, operate under somewhat different conditions. Municipalities which have owned their water systems for long periods and have wisely managed them are either debt free or have small indebtedness. It is believed that the revenues of such municipal water works essentially consist of the sum of the requirements for operating and maintenance expenses, depreciation reserve, and the average annual needs for additions and betterments. This sum constitutes the amount to be collected from consumers within the city who are the stockholders in the municipal water plant.

The situation for service supplied by municipal plants to consumers located outside the city differs materially. Service to such outside consumers should be strictly on a utility basis. These consumers should pay rates adequate to yield a fair return on the fair value of the property. Under these assumptions, the inside-city consumers get their water substantially at cost, whereas the outside-city consumers pay higher rates in order to yield a fair return on the value of the facilities provided and paid for by others. Recently, in two cities in which inside and outside rates were figured on this basis, the outside rates were approximately 175 per cent of those inside the municipality.

Municipal plants should develop a sound financial policy designed eventually to retire indebtedness and get on a "pay as you go" basis. When this result is accomplished, the revenues collected through rates should be sufficient to pay operating and maintenance expenses; to provide an amount sufficient to cover ordinary additions to the water works such as distribution system extensions and meters; and to furnish an additional amount to cover the average annual requirement for major additions, this sum being apportioned and impounded during the period between such major additions.

Such a policy followed over a long period will result in the cost of water works expansion being approximately 40 per cent less than it would be under debt financing. Costs are amortized as incurred without interest charges.

Financing from revenues in municipal plants has the following advantages: 1. It provides new construction when needed without resorting to bond issues.

2. It avoids possible delays incurred by voting on bond issues.

3. It avoids the political exigencies which arise when bond issues are presented.

4. When such a financial program is properly developed in connection with a comprehensive construction program, the bulges in fixed charges due to bond issues are avoided.

5. The consumer's attention is focused upon service rather than cost, which is the main consideration when bond issues are presented.

6. Financing new construction from revenues reserves to the water department rather than the politician the control of its ability to finance, construct, and maintain high-quality service.

Conclusion

Good management does not just happen. It is created. Conferences in which mutual problems are discussed and experiences exchanged contribute to better management. The better the management, the fewer the problems that recur. Anticipation is superior to correction. The key to good management is planning, coordination, and timely execution of construction, financing, and operating procedures in a manner to meet the approval of the greatest proportion of the water users.

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Satisfied customers are worth more to us than revenue secured from water uselessly passing through meters.
INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak		Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	◯	47,600	1,451,800	$156.21
¼"	◯	12,300	375,150	60.05
⅛"	o	3,200	97,600	19.65
1/16"	o	860	26,230	6.35
1/32"	•	215	6,550	1.97

(Above estimates are based on Indianapolis pressure without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Administration of Small Water Plants

By WENDELL R. LA DUE
Chief Engr. and Supt., Bur. of Water and Sewerage, Akron, Ohio

WHAT is administration? The words management and administration are synonymous and mean the conducting or carrying on of affairs—of a business, for example. That business can be a water works. An error is frequently made in thinking of the large-plant man and the small-plant man as two different kinds of men. In fact they are not, for they are the same kind of man in constant and daily need of different approaches to the same kinds of problems. Progress in solving the management problems of the small plant cannot be made by driving imaginary wedges between large water utilities and small ones, or by assuming that one is enlightened, well meaning, and knows all the answers, and the other is not and, therefore, must be "managed."

When does a plant cease to be "small" and become "large"? There are now more than 100,000,000 people in organized communities in this country who receive safe and dependable water supplies from publicly and privately owned water utilities. On the average, this service is supplied by one employee for each 1,250 people served. In other words, 80,000 people serve 100,000,000. This is big business ,whether a community is served by 5 or 5,000 employees. These 80,000 persons, each possessing an almost infinite variety of skills, training, and talents, every day of the year without ceasing, are contributing unselfishly and selflessly of their energy, ability, and ingenuity to the biggest business, in tonnage, in the United States. There is no precise or scientific way by which the achievement or contribution of each can be measured. But this is not important. It is necessary, though, that the water works profession foster among its members a broad and sympathetic understanding of the mutual responsibilities and problems of small and large plants. Such an understanding among water works men will result in greater encouragement from the public.

Why should the water works industry improve its administration? Good management is the result of a combination of continuing policies, including expansion of both facilites and operations, sound financing, efficient conduct of business, and satisfying services. Good management is as essential for small plants as it is for large water works systems. All too often management is considered to be confined to the direction of more or less routine operating functions. In a practical sense, it must include sound planning for the future and the coordination of needs, plans, and accomplishments with the financial obligation and ability of the community to support them.

Water Works Administration Committee

The water works profession will accomplish much to improve its own status if it can produce an enlightened and progressive top management. The purpose of the American Water Works Association's Committee on Water Works Administration is to do just that, as illustrated by the purposes of its various subcommittees:

Constitutional and Statutory Aspects of Municipal Water Works Organization—charged with the duty of studying existing state and province laws and municipal ordinances, and formulating principles relating to types of municipal water works organizations.

Radio and Mobile Communication Facilities for Water Works—charged with the study of the use of radio and mobile communication facilities available for water works, together with the collection of data on the use of radio in the water works field. The committee has a continuing interest in federal activities affecting wave allocation to utilities.

Water Used in Air Conditioning and Other Refrigeration—charged with the study of the problems arising from the use of water in air conditioning and other refrigeration and to recommend policies as they affect water works (and sewage) facilities.

Water Use in Fire Prevention and Protection—charged with the study and evaluation of methods of fire prevention and protection and of protecting sprinkler systems from freezing. This committee may be expanded to meet the pressing problem of renegotiation of insurance contracts to meet the demand sensed in increased costs of replacement.

Public and Worker Relationships—charged with: [1] considering and proposing to the Board of Directors activities on behalf of the Association in the field of public relations; [2] the production of guidance material in the field of public relations; and [3] the review of material which is in process of production by the Association.

Compensation of Water Works Personnel—charged with the gathering of comparative material and data and the formulating of a general schedule of compensation for water works personnel and management.

Pension and Retirement Plans—charged with the duty of collecting information upon, and promoting the adoption of, pension and retirement plans in the public water works industry, as well as the study of developments in the industrial field and their effects upon public employees.

Safety Practices—charged with the preliminary study of personnel safety and working conditions in plant facilities and physical structures. This study may be extended later to the border field of public safety in water utility construction work. This particular field of management is attracting nation-wide attention.

Taxation and Revenue Allocation—charged with the assembly and study of data on the taxation of water works systems and the diversion of funds from the water works utility to other activities, and the formulation and distribution of basic principles of good management of taxation and revenue allocation.

Water Main Extension Policy—charged with the study of the problems involved in the extension of water mains, both within and without the corporation limits, including a digest of enabling legislation.

Water Department Reports—charged with the review of existing annual reports of water works organizations and the preparation of recommendations on content and style of annual reports.

Water Rate Schedules—charged with the consideration of the fundamentals of water rate structures and the outlining of the policies upon which rate schedules may be developed in order to distribute equitably the funding, operating, and maintaining of water works utilities.

Water Use—charged with the collection and evaluation of data on:

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1. Industrial water use, encompassing the water requirements of specific industrial operations and involving the collection of information from units in the same industry over a wide geographic area, in order that water requirements per unit of product may be tabulated.

2. Domestic water use, encompassing the collection of data from a number of water utilities from which a breakdown is available to show per capita water use in different types and sizes of residences and various classes of commercial establishments.

Forms of Management

Is it not possible that these problems of administration result from the inadequate attention that is given to the fundamental reasons for their occurrence? Does not water works management spend its time discussing the results of inadequate management, whereas it ought to be doing something about analyzing the causes, diagnosing the resulting weaknesses, and then taking the steps necessary to correct them? Realizing the impractical multiplicity of state laws, local ordinances and charters, is this truly not a challenging problem? At the very outset, water works men themselves become quite philosophical and altruistic in realizing and appreciating the other fellow's position. The ramifications are many but the generalities few.

There are many cities in which the water works management is directly under the city council, the personnel of which, by nature, is continually shifting. In such a setup, centralized top responsibility is generally slight, as there is no real concern about long-range planning for the work of later administrations. There are very often too many potential "bosses," and the superintendent, no matter how efficient, may be subject to change with the city administration.

Water works management under the city manager form of government is only as good as the city manager, who, in turn, is subject to the changes and whims of a council or other elected board of similar nature. When a city manager is changed, his appointees usually go with him.

A third general form of top management is that of the special water works commission, usually consisting of three to five men with overlapping terms of such lengths that, in general, no one political administration can upset the board by a majority of new appointments. Such a board is responsible to no one but the public which it serves. It is nonpolitical; its continuity is assured and it attracts to its membership the best qualified men of the community. This form of management lends itself to a continuity of employment of water works personnel; the maintenance of high efficiency; the establishment of constructive, continuing policies on construction, operation, and rate stability; and the furnishing to the consumer of a maximum of satisfying service at a minimum of justifiable expense and cost.

In all local organizations, management is brought face to face with one of the most baffling challenges of human nature and behavior: "People get and do what they want, good or bad." When a superintendent in the near-perfect protection of an ideal, commission-operated water works asks why a certain city countenances the shortcomings of some council-controlled operation, the only answer forthcoming may be "Because they (the people) want it and like it that way." For this reason, regardless of its logic, a uniform type of top management is not always potentially possible or perhaps even actually desirable. Past history and local conditions will weigh heavily and must be considered.

Legislation

It appears quite evident that practically every undertaking of a water department is connected in some way with the basic and enabling legislation applicable to the actual organization of any department in any particular state. Water works management must be continually aware of this constantly changing legislation. Pennsylvania affords an outstanding example of this observation. Under the "Authorities Act" of 1935, 71 water works management and ownership groups were functioning in 1950.

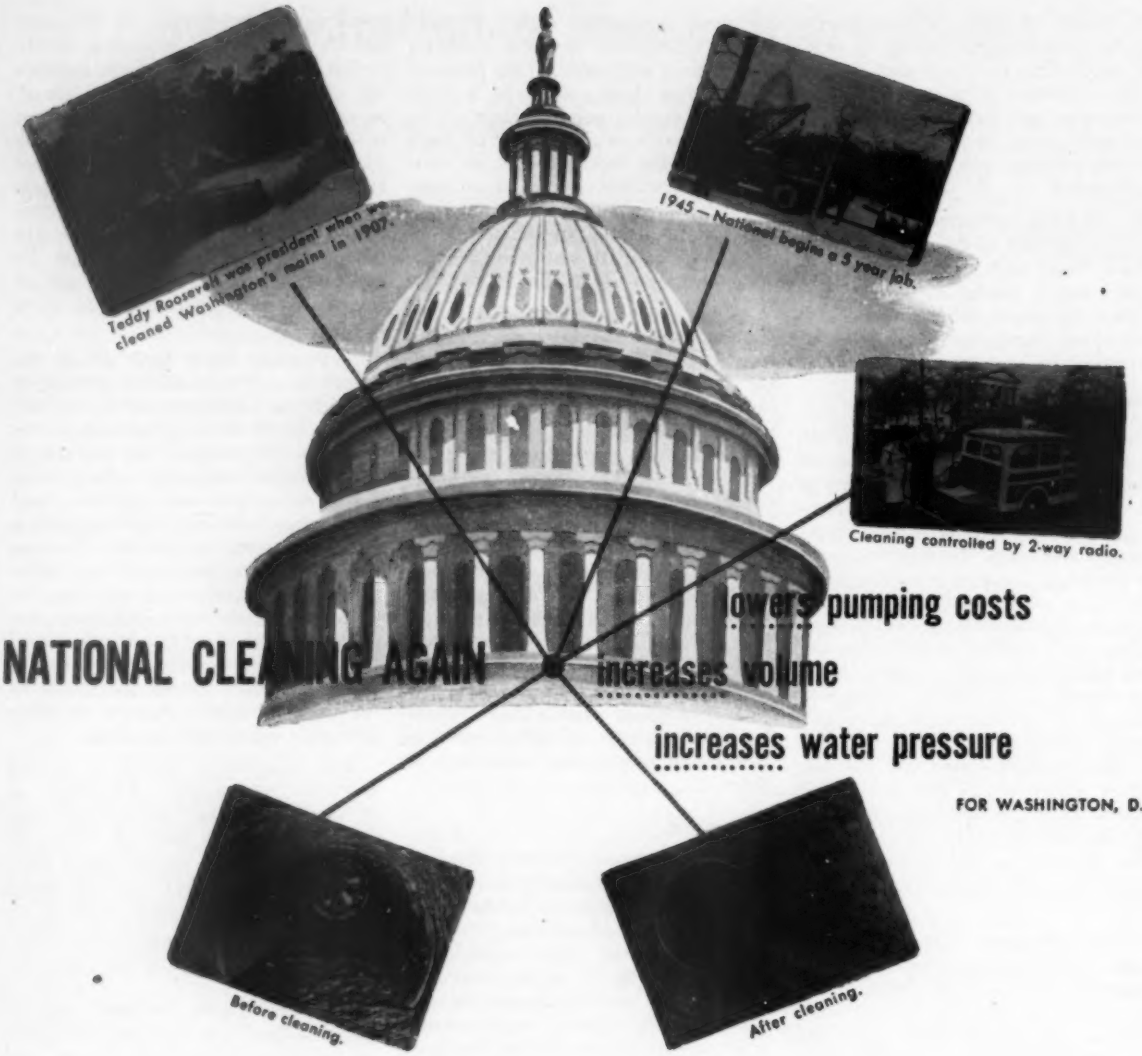
The series of legislative enactments known as the "authority acts" permits the citizens of a single city or town or of groups of incorporated and unincorporated places to establish an agency through which governmental units may provide needed facilities and services for themselves, upon a self-liquidating basis, in the manner of private industry and without obligating the pre-existing units of government. Such an authority is authorized to file liens for debts owed, is given the power of eminent domain (but not the power to acquire a water works or other system by condemnation), can sue and be sued, and can issue revenue bonds, but may not obligate the municipality. The life of an authority under the Pennsylvania acts is limited to 50 years, whereas bond issues are limited to 40 years and the maturity of refunding bonds is restricted to the life of the authority. At the termination of the life of an authority, its property may revert to the municipality of municipalities which incorporated it. One further stipulation, which is of great value, requires that for the period during which authority revenue bonds are outstanding, an engineer must be retained by the authority to advise it on matters of planning and management.

Authorities have been given the power to assess benefited properties for the cost of improvements in proportion to the benefits received, giving them, in this respect, an advantage over private companies which must establish a rate structure that will make them entirely self-supporting from revenues or rentals. Private companies are permitted no other sources of income and may not be parasites on any municipal funds, except, possibly, when a system is leased to the municipality for operation. On the other hand, authorities cannot be deprived of their revenues to carry out other municipal functions.

The populations served by various Pennsylvania water authorities in 1950 varied from 700 to more than 100,000. By the end of 1947, 65 water authorities served more than 1,300,000 consumers and the total assets of the group were in excess of $101,250,000.

Conclusion

The procedures discussed support the idea that there is no real difference in the objectives of the "large" and the "small" plant. The author gives well-deserved praise to the small operator. He has sometimes been compared to a one-man ball team. Just as busy, he pitches the ball, runs behind the plate to catch it, and, if it is hit, he runs to the outfield to catch it, or attempts to put out the runner, all by himself. In other words, he treats the water, operates the plant, distributes the water, reads the meters, bills the customers, and collects the money, all with the utmost confidence that things will "come out all right in the end." The large-plant operator may be compared to the president of the league, but he has no more fun, nor do his customers have more confidence in him than in the small operator. The author knows no other career that affords a greater sense of inner satisfaction to those who embrace it successfully nor another business in which there is greater determination to do a better job.


Teddy Roosevelt was president when we cleaned Washington's mains in 1907.
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Before cleaning.
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lowers pumping costs

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increases water pressure

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Uprating Distribution Systems By Cleaning and Cement Lining

By J. A. FRANK
Vice-Pres. and Gen. Mgr., National Water Main Cleaning Co., New York, N.Y.

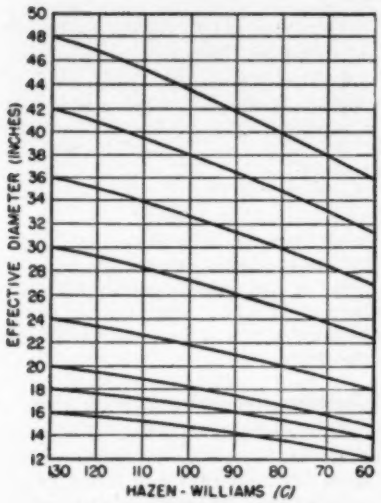

Fig. 1—Curves Revealing Loss of Effective Pipe Diameter as Tuberculation Increases—Likewise Recovery of Line Capacity Through Main Cleaning.

BECAUSE additional loads are being placed on distribution systems and, further, because the cost of new pipe lines is increasing very rapidly; the rehabilitation of distribution systems by cleaning and lining is coming into common practice as the least expensive and quickest method of obtaining additional capacity. In so doing the useful life of the rehabilitated main is extended many years and the recovered capacity is assured of being sustained therewith.

There are many improved practices in both cleaning and cement lining and, with proper scheduling, work can be done much more quickly than in earlier years.

Some Modern Practices

The cutting of cast-iron pipe has long been a laborious, tricky and uncertain job and there is a decided trend toward the use of machines for this work. In the smaller pipe the use of a wheel-type cutter has been standard practice but, unfortunately, it cannot be used with any degree of satisfaction in sizes over 10 in. There are a number of methods which have come into use in the last few years for cutting the larger sizes of cast-iron pipe. The first of these methods utilizes a split machine which is clamped around the pipe. One or more tool bits of the partingtool type travel around the pipe, cutting the metal with a straight even cut.

The second method utilizes a pipe-cutting machine which travels around the pipe on a track of chain. The power unit, which is either an air or an electric motor, is connected through a gear box to a rotary saw which travels around the pipe, removing the metal with a straight even cut.

The third method utilizes the electric arc-welding machine, which produces good cutting results by the use of a negative polarity rod in straight polarity. It is necessary to have a high output machine and a special technic is required of the welder handling the electrode. Under proper conditions this method can be very rapid and result in an even true cut.

Various methods of combining the electric arc and oxy-acetylene have been used such as the oxy-arc. In general, these combinations are very fast and very effective, but unfortunately the overall cost of cutting pipe is usually quite high using these methods.

The development and utilization of these four methods of cutting have resulted in speeding up the work of cleaning, and the even cuts made possible by them permit the use of the nipples taken out of the pipe, thus reducing costs for material on the job.

The installation of the pipe cleaning tool into the main has long been a laborious and time-consuming job. In recent years, methods have been developed for inserting the cleaning tool so that it now is comparatively easy and takes only a few minutes.

Present-day pipeline fittings serve as another means of speeding up cleaning. By the use of mechanical-type couplings, such as Dresser, Skinner or Simplex, coupling up of the pipe after the cleaning machine has been inserted now requires only a few minutes, as compared with the practice of yesteryear which sometimes consumed hours.

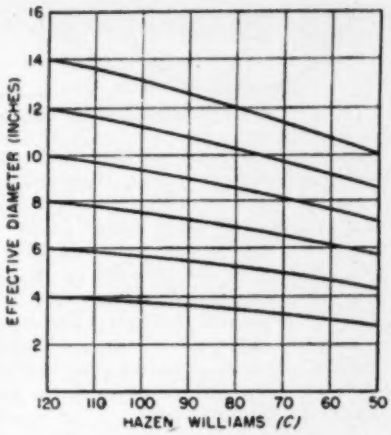

Fig. 2—Curves Revealing Loss of Effective Pipe Diameter as Tuberculation Increases—Likewise Recovery of Line Capacity Through Main Cleaning.

Another factor in speeding up the cleaning process has been the accumulation and compilation of data on the required flow and pressure to propel the cleaning machine at the most effective speed of travel through the line. It is now possible to predict with reasonable certainty what pressures and quantities of water are going to be required to propel the machine and the approximate speed at which it will travel. With this knowledge, the work can be scheduled and laid out so that many former uncertainties no longer exist.

One of the most recent developments in connection with water main

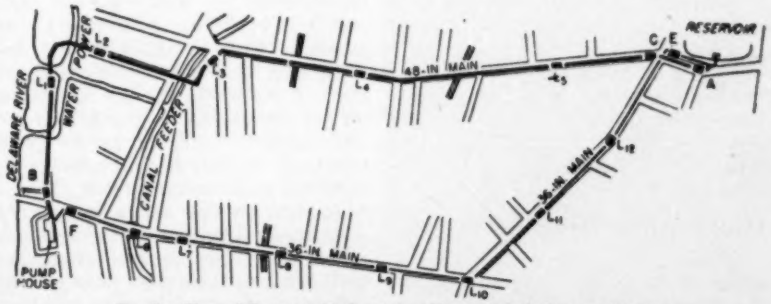

Fig. 3.—Plan of Trenton, N. J., Mains Cleaned and Cement Lined.
(Stations of entry and egress of cleaning machine and lining apparatus are indicated.)

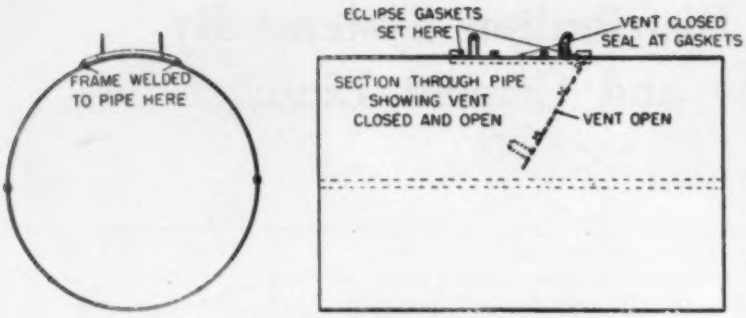
ECLIPSE GASKETS SET HERE
VENT CLOSED SEAL AT GASKETS
FRAME WELDED TO PIPE HERE
SECTION THROUGH PIPE SHOWING VENT CLOSED AND OPEN
VENT OPEN

Fig. 4—Automatic Air Vents Installed on Trenton Steel Mains.

cleaning is the use of the two-way radio for communicating from point to point and controlling the job. In the cleaning of large mains in distribution systems we are faced with the problem of the disposal of large quantities of pipe cleaning water in heavily populated districts. The use of the two-way radio insures shut-offs before any damage can be done in the event of any failure of facilities to carry off the water.

Some Graphic Comparisons of Main Conditions

Figures 1 and 2 constitute curves which illustrate the effect of the roughness of pipe interiors on carrying capacity. Some average coefficient for new pipe had to be assumed and in these curves the Hazen-Williams C value of 130 has been assumed for pipe 16 to 48-in. in diameter, and 120 for smaller diameters.

Figure 1 covers pipe in the sizes from 16 to 48 in. To read the uprating of a pipeline by cleaning, note that a 48-in. line with a coefficient as high as 115 has an effective diameter of 46 in. only. That 2-in. diameter loss represents a sizeable non-yielding investment in the 48-in. pipe that has but 46-in. service value. In this size pipe, cleaning would restore the main to 130 and the effective diameter to 48 inches.

Figure 2 covers pipe from 4 to 14 in. in diameter. A 14-in. pipe with coefficient of 80 would have an effective diameter of 12 in. only. In carrying capacity the loss is considerably greater, however, than the 14.3 per cent loss in effective diameter. By cleaning, this effective diameter can be increased to 14 inches.

As an example of successful restoration of an old line to satisfactory carrying capacity, a record of operation in Trenton, N. J., will be reviewed.

Main Rehabilitation in New Jersey

Water for the city of Trenton is obtained from the Delaware River. An intake, built out into the river, supplies water to the suction side of low-lift pumps, whence it is pumped to the filter plant and there treated. The treated water flows by gravity to the suction side of high-lift pumps and is then carried through two ascending mains to the service reservoir which has a capacity of approximately 60 mil. gal. One of these ascending mains is a 48-in. lock-bar laid in 1907. The other ascending main is a 36-in. cast-iron bell-and-spigot laid in 1870. Figure 3 shows the plan of these two lines.

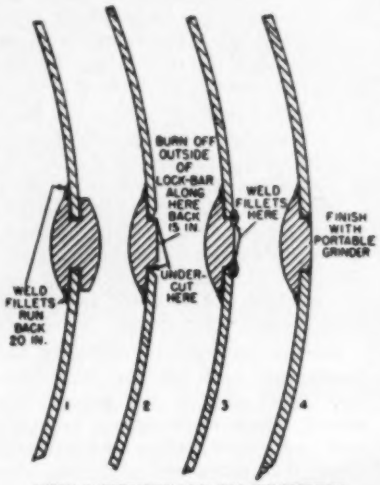

Fig. 5—Steps in the Preparation of Lock-Bar Pipe for Dresser Couplings.

During the summer of 1940 it was decided to appraise these lines, determine their condition and lay out a suitable plan to insure their life. Since the lock-bar line was made of plate only 5/16 in. thick and, because access manholes were available, it was decided that this should be inspected first. Accordingly the line was shut off and dewatered. A manhole cover was removed and an access plate taken off so that it was possible to enter the main and inspect it. It was found that the line was in remarkably good condition considering its length of service. Very little tuberculation and no incrustation were present. The original coating had been an excellent job, but in numerous places it was completely gone and the bare steel was exposed. At the points where the steel was exposed, evidences of deterioration could be seen. After inspection the access plate was bolted up and the line restored to service.

Since the 36-in. ascending main had no access openings, inspection would have been extremely expensive. Therefore, tests were made on Aug. 29, 1940, to determine the coefficient of each line. The 48-in. lock-bar was found to have a coefficient of 108. The 36-in. cast-iron line was found to have a coefficient of 66. During the fall of 1940, plans were made for the rehabilitation of these two lines and in the spring of 1941 work was started which would eventually result in cement lining in both these lines *in situ* by a centrifugal process. It was decided to clean and cement-line the 48-in. line first and, after this was back in service, to clean and cement-line the 36-in. line.

Cleaning and Lining a 48-in. Line

In cleaning a steel line of this size there are a number of factors which must be considered, and planning and scheduling must anticipate these problems.

Because of surges which may occur during cleaning, with resulting negative pressures, it is imperative that air vents capable of handling large quantities of air be installed. These air vents, or vacuum breakers, preclude the possibility of collapsing the pipe when, for any reason, a vacuum occurs in the line. Figure 4 shows the air vents which were designed and installed for this purpose.

As can be seen in the figure, the installation of such an air vent is rather simple. Using the plate of the air vent as a template, the welder cuts

Fig. 6—Centriline Pipe Lining Machine in 36-in. Main.

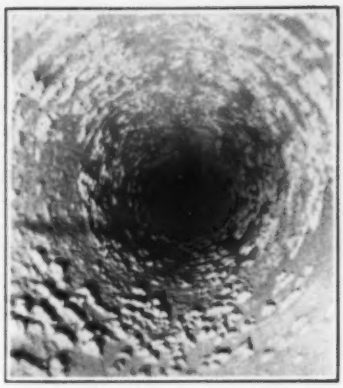

Fig. 7—36-in. Line of Trenton Before Cleaning.

around all four sides of the plate after having set the plate so that its center line is on the vertical axis at the top of the pipe. The plate cut out is then removed and the hole in the pipe trimmed up. Then the frame for the vent is centered up over this hole and a heavy bead placed all around the frame on the outside. The gasket is then installed, the plate part of the vent lowered into the pipe and wedged up until ready for use.

The cleaning of the 48-in. lock-bar entailed the installation of two such vents; one in the nipple where the machine was introduced and the other at a point where access was had to determine whether or not there were stays in the line.

The vents gave two orifices at high points in the line, rectangular in cross-sections, 18-24 in., through which air could enter the line, and obviated all danger of collapsing the pipe.

Another danger in cleaning a line of this size is in allowing the machine to come out of the pipe, particularly on a down-hill shot. This danger obtains because of the piston effect of the machine. Should it be allowed to emerge completely, the sudden drop in water pressure in the line could conceivably cause the pipe to collapse. There is also the danger of spilling the tremendous quantities of water through the unobstructed pipe. To prevent this, it was necessary to build a very strong bulkhead in the hole where the machine was to make its exit, so that only part of the machine should leave the pipe and the piston-like skirt remain in the main, thereby causing the water to drain out of the line comparatively slowly. Plans for these bulkheads were made before the work started.

Fig. 8—A Section from the 36-in. Steel Main Reveals the Urgent Need for Some Form of Rehabilitation.

One of the problems to be considered in this job was the coupling up of lock-bar pipe. It was decided to use Dresser couplings for coupling up the nibbles cut out for the entrance and exit of the cleaning and lining machines. Figure 5 shows the steps in the preparation of the pipe.

To prepare the pipe for the use of Dresser couplings it was necessary to cut off the outside of the lock-bar. The method used was to run two electric arc fillets along the inside joint of the lock-bars, both top and bottom, for a distance of 20 in. at both ends of the nipple. The lock bar was then undercut on the outside as shown in Fig. 5, and a fillet thrown on the outside which was finished off with a portable grinder, thus presenting a smooth surface on which the gaskets of the Dresser couplings could make a good seal. As can be seen from Fig. 5, the electric arc weld on the inside runs back for 20 in. and the cut of the lock-bar on the outside extends only 15 in. This overlap obviated any danger of a leak at this point. The lock-bars on the pipe projecting into the hole in the ground were treated in the same way except that the fillet on the inside was extended back only 12 in. and the cut on the outside 8 in. The Dresser couplings used had a width of 15 in. so that by placing the couplings on the nipple and dropping the nipple into place, then sliding the couplings over the pipe projecting into the hole, it was possible to center the Dresser sleeves over the cuts in the pipe.

An important step in planning such work is the selection of entrance and exit points for the cleaning machine. The exit point is particularly important because here it will be necessary to dispose of large quantities of water. After a careful study the points were selected and the planning phase of the job was completed.

Work was started on June 2, 1941. Three excavations were made for the cleaning, which involved shooting a cleaning tool by water pressure from the reservoir back to the pump station. An excavation, as close to the reservoir as possible without undue

Fig. 9—Barrel of 48-in. Lock-Bar Main After Cleaning.

interference with the fittings, valves, etc., was made on the 48-in. line. This excavation was 12 ft. long, 8 ft. wide and 10 ft. deep, which left 2 ft. of working room all around and under the pipe. In Fig. 3 this excavation is shown at (A) on the plan. So that the large quantity of water discharged during cleaning could best be handled and emptied into the Delaware River, the exit excavation was made 100 ft. back from the gate at the pump house. This excavation was made at (B) on the plan. It was 12 ft. long, 8 ft. wide and approximately 10 ft. deep. The 2 ft. of working room around the pipe, which had been the objective, was interfered with in two places. At one point an 8-in. service main running from the pump house to the filter plant projected into the hole; on the other side a 60-in. concrete sewer cut down on the working room. This hole was "tight-sheeted," using 3x10 tongue-and-groove sheeting. On the side of the excavation nearest the river the sheeting was cut low and a flume fitted into the notch thus made. A flume 50 in. wide, 25 in. high and approximately 250 ft. long was constructed to convey the water overflowing through the notch in the sheeting into the Delaware River. Every effort was made to see

Fig. 10—The Completed Job on the 48-in. Main—and Good Now for at Least 50 Years More, with Sustained Delivery Capacity.

Installing 10" U. S. centrifugally cast iron pipe for a water distribution system

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Fittings (flanged) are made to conform to American Standard Specifications Class 125 (B16.1) and Class 250 (B16b) or long-body A.W.W.A. type.

Mechanical joint for cast iron pipe and fittings is made in accordance with American Standard Specifications A21.11. Pipe and fittings can be furnished with cement lining in accordance with American Standard Specifications A21.4 or manufacturer's standard.

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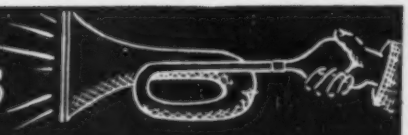

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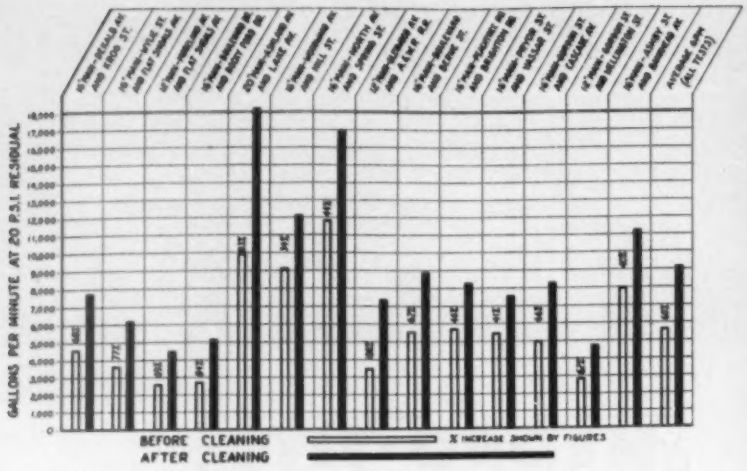


Fig. 11—DIAGRAMATIC comparison of main cleaning results, Atlanta, Ga.
Gal. per min. delivery increase is shown as percentage figures.

Fig. 12—MODERN tool for cleaning water mains.

that all preliminary work was completed before taking the line out of service so that the length of time the water was pumped through a single line—and the consequent higher pumping costs—would be held to a minimum.

After all preparations had been made, the 48-in. lock-bar main was taken out of service on June 11. The line was shut off and the air valves checked to make sure they were in working order. A blowoff at a low point was opened and the line dewatered slowly to avoid the danger of pulling a vacuum and collapsing this steel pipe. The dewatering process took from noon on June 11 until 8 a.m. on June 12.

Using the oxy-acetylene torch, a nipple 6 ft. 6 in. long was cut out of the 48-in. pipe at (A). Actually three cuts were made as 1 in. was cut off the nipple so that it could be easily put back into the main by using Dresser couplings. The nipple was lifted out of the ditch so that one of the automatic air vents (Fig. 4) could be installed; the cleaning tool was then jacked into the nipple and the lock-bar prepared for Dresser couplings, as illustrated in Fig. 5. The nipple, with the machine in it, was dropped into place in the line and coupled up with Dresser couplings.

A nipple was cut out at the exit hole and a bulkhead built to prevent the complete emergence of the cleaning machine and all was ready.

Through the co-operation of the Trenton police it was possible to secure the services of two two-way radio cars to facilitate the control operations. This was accomplished by leaving one radio car at the control valve so that the operator could immediately relay any instructions to the valve crew. The other radio car was used in following the machine so that it was possible at all times to increase or decrease the flow behind the machine.

Machine Speed Control Important

When all was in readiness, the valve was slowly opened behind the machine until the pressure reached approximately 8 lb. The machine started off and proceeded at a slow rate through the pipe. The last 2,000 ft. of this line have a very sharp down-grade. As soon as the top of the grade was reached, the large quantity of water contained in the 5,000 ft. of pipe behind the machine was converted into head and, as the pressure increased, the speed of the machine increased so that its travel through the last 1,500 ft. was very rapid. During the shot it was found that with a pressure of approximately 8 lb. behind the machine, water at a 22-mgd. rate was consumed.

An inspection of the pipeline after this shot showed that, at the beginning of the line where the progress of the machine had been slow, the cleaning was a thorough job, but that the last 1,500 ft. of the shot had not given a very good cleaning job due to the rapidity with which the machine had traveled through this section of pipe. It was decided to shoot the machine again to see if it would be possible, by shutting off the water before the down-grade was reached, to control the speed of the machine so that a more thorough job of cleaning could be accomplished. This was attempted on June 20, 1941, but it was impossible to hold down the speed of the machine to a desirable point.

Two-Way Cleaning Proves Meritorious

It was then decided to shoot the machine uphill, that is, from hole (B) (in Fig. 3) toward hole (A), using the pumps at the pump station as a source of pressure. This necessitated the "tight-sheeting" of the hole at (A) and the building of a rugged bulkhead at this point so that the machine would not come all the way out of the pipe with a resulting surge of water.

The fact that the point where the wash water was to be disposed of was in a rather heavily populated district presented another problem in shooting uphill. It was necessary, therefore, to make a survey of the sewer system in the area to determine how to dispose of the large quantity of water which would be discharged during the shot. The problem was solved by sandbagging along the curbs of the streets and distributing the load over a number of large storm sewers. When all of the preparatory work was completed the machine was shot uphill and, in this process, it was possible to control its speed very accurately, using the radio cars as a means of communication with the pump house.

After this uphill shot the line was found to be properly cleaned and was ready for the cement lining.

Lining Operations

The 48-in. cement-lining machine is powered by an electric motor and travels through the pipe, applying the mortar centrifugally as it travels. It is followed by adjustable rotary trowels. Current for the motor is supplied through a cable which is run inside the pipe back to a mobile alternator. As the lining machine travels back through the pipe, the cable is

pulled toward the alternator and wound up on a reel.

The cement mortar is mixed in a mobile wet batching machine. The mortar is dropped through the chute at the hopper and into rubber-tired buggies placed below it inside the pipe. The buggy, full of mortar, is pushed to the lining-machine, the mortar transferred to the hopper of the lining-machine and the buggy of the lining-machine and the buggy returned for another load of mortar.

Figure 3 shows how the lining machine was inserted in the pipe at the hole near the filter plant and run back toward the pump station. The batching machine and the alternator were located at this hole and the pipe was lined from the gate at the pump house back to the hole. The batcher and the alternator were moved to the first access hole, the nipple dropped into place, coupled up and the machine placed the lining right through the nipple.

Because of the mortar transportation problem it was necessary to have small holes about every 1,000 ft. so that the wet-mix concrete could be dumped through a chute into buggies on the inside of the main at these points, and transported for shorter distance to the lining-machine itself. It will be seen on the plan that there were a number of small excavations where this was done. After the lining was completed, the manholes were bolted back and the lining was made one continuous cylinder right past these access manholes.

When the exit hole at the far end was reached, the machine was turned around and sent up into the pipe at the far end. The pipe was lined back to the hole, the lining machine lifted out of the hole, the nipple lined up on the ground, lowered into place and coupled up. Thus a continuous lining was provided from one end of the line to the other.

The line was sterilized and put back in service on July 31. The sterilization was accomplished by feeding water containing chlorine to the extent of 60 ppm. and running it right through into the reservoir. Although this water as it entered the reservoir had a very high residual, there never was detected any increase in residual in the distribution system.

With the 48-in. line back in service —it had been out of service only 38 working days—it was now possible to go ahead with the cleaning and cement-lining of the 36-in. line.

Cleaning and Lining a 36-in. Line

The 36-in. line was laid in 1870 and there was no record of some of the older connections to it. This line was shut off on Aug. 1, 1941, and with the 36-in. line off, a test was run on the 48-in. line for leakage. We were unable to measure any leakage in this line after cleaning and cement lining, although the test was run over a 24-hour period.

Fig. 13—CLEANING tool used prior to cement lining.

On Aug. 2 the 36-in. line was dewatered by running the water out through a 16-in. side connection. An attempt was made to cut the cast-iron pipe by means of the electric arc at the point (E) which was to be the entrance hole for the cleaning machine. The attempt was not successful because it was impossible to obtain an electric arc welder having a capacity larger than 200 amp. and, for the successful cutting of this thickness of cast iron, a machine of at least 600-amp. capacity is required. This nipple was finally cut out using an oxy-acetylene cutting torch of special design and the results obtained with this method of cutting were very good, as were the results of the cutting at the exit hole (F).

The 36-in. cleaning machine was placed in the nipple which had been cut at (E) in Fig. 3 and, on the night of Aug. 5, when everything was in readiness, the shot was made.

In the course of this shot the machine negotiated two short-radius 90-deg. bends. Examination of the pipe showed that a very good job of cleaning had been done but that an additional shot would be necessary to attain the smooth condition needed for a good cement lining job.

A second shot was made during the night of Aug. 6 and examination of the pipe after this shot showed that an excellent job of cleaning had been done and that the pipe was ready for cement lining.

Fig. 6 shows the 36-in. lining machine operating within the main.

Access for cement lining was had at a number of points indicated on the plan (Fig. 3), and manholes were fabricated by drilling a series of holes making a circular piece which could be broken out of the top of the pipe. A saddle was then fastened to the pipe and a cast-iron plate fastened in this saddle. No particular difficulties were experienced during the lining of the 36-in. pipe and the work was completed on Aug. 21, 1941. The line was sterilized, using the same quantities of chlorine and procedure employed on the 48-in. line.

Results

A test for capacity and coefficient was made on these two lines more than two years later. The 48-in. line was found to have a coefficient of 144 and the 36-in. line a value of 135, as compared with 108 and 66, respectively, before rehabilitation. These coefficients are corrected for the reduction in area due to the thickness of the cement lining.

The reduced friction loss results in considerable power saving, amounting to from 15 to 17 per cent.

Fig. 7 shows the 36-in. line before cleaning. Note the flow-impeding tuberculation.

Fig. 8 shows the condition of a portion of the steel main discovered during the lining process. It can readily be seen that the corroded and pitted condition was serious and would soon have led to trouble.

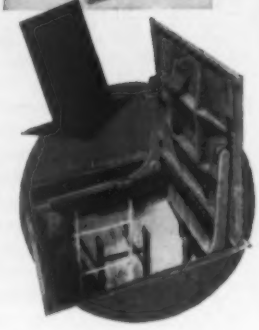
Fig. 9 shows a section of the 48-in. main after two-way cleaning and ready for cement lining.

Fig. 10 is a view of the same line after lining. The lining is extremely smooth. The illusion of rings or large circumferential corrugations is a light reflection phenomena.

Another result of the cement lining is that the old lines have been made bottletight. In the five-year period preceding the cement lining of these two mains, leakages bad enough to need repair were found on the average of eight times per year. Since the completion of this work in 1941 not one leak has been discovered on the 48-in. line. In addition, a test run on the 48-in. and 36-in. lines together showed a leakage so small that it is practically impossible to measure it.

The job has been of great benefit since costly repairs, which would have been necessary, have been obviated. The two lines are bottle-tight and the friction loss has been reduced so that pumping costs are held to the value for new pipe.

Another advantage, which is difficult to evaluate, is that the life of the failing lockbar line has been increased at least 50 years. This, in itself, is



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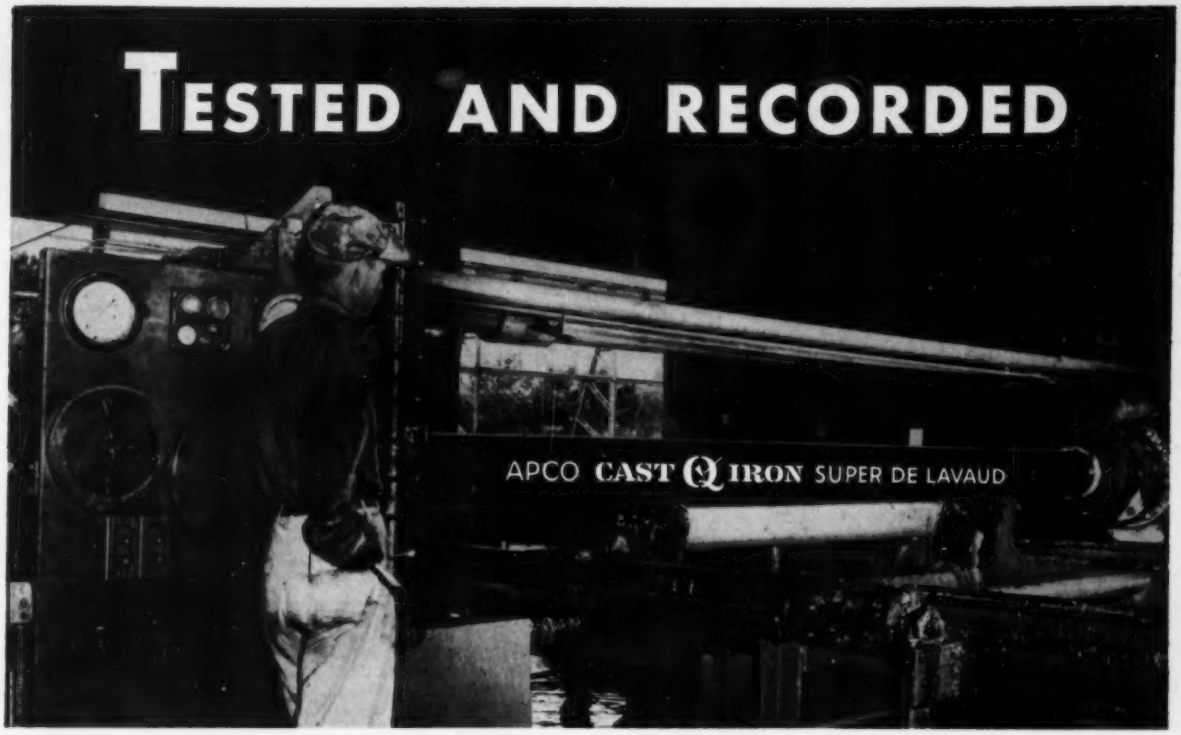

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During the latter part of 1952 and the early part of 1953 these two lines were cleaned and cement lined. Prior to the cleaning and cement lining, the coefficient of the 24-inch line had dropped to 94, and the coefficient of the 20-inch raw water line to 98. After cleaning and cement lining, the 24-inch line had a coefficient of 136 and the 20-inch line had a coefficient of 139. Since the water which passes through these two lines is pumped, the power saving is, of course, substantial and it will not be necessary to clean these lines repeatedly as has been the practice in the past.

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by EMIL L. NEUBLING
for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1⅛	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.18	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

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HYDRAULIC METHOD

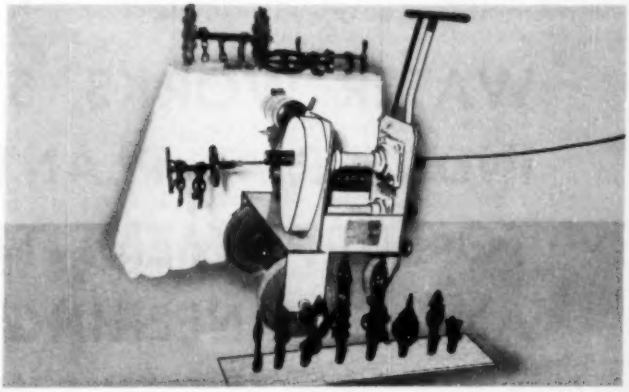
•

Water, Gas, Oil and Process Pipes, from 4″ I.D. to 60″ I.D. are cleaned by this method. The cleaning tool is placed in the pipe at one opening, and propelled to the discharge opening by water pressure. Sufficient water is permitted to by-pass the cleaner to flush loosened deposits from the pipe. These tools will clean around 90° bends and through open valves.

RODDING METHOD

•

Flexible Spring Steel Rods, to which are attached suitable cutters and tools, are rotated through the pipe by gas, or air powered rodding machines. Flush water conveys loosened debris from the pipe. Water, gas, oil, and process pipes from 2″ I.D. to 36″ I.D. and distances up to 900 ft. are cleaned by this method. Openings and out of service time are kept to a minimum.



WINCH METHOD

•

Self opening and closing buckets are drawn through the pipe from one opening to another by power winches. The buckets remove the debris to the surface. Special accessories such as slitters, scoups and collapsing and expanding drags, are used to break up deposits so they may be removed by bucket.

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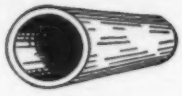

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Steel Tanks as Distribution Reservoirs

Lower construction and maintenance costs are important features

By C. KENYON WELLS

Asst. Gen. Mgr. and Asst. Chief Engr., Long Beach Water Dept., Long Beach, Calif.

IN every growing community, the water works operator is constantly faced with the problems of water system expansion. The orderly development of a water system is dependent upon continual and intelligent planning, always projected several years into the future. Moreover, this type of planning is imperative if a water system is to expand economically, continue to operate efficiently, and serve the community adequately.

Foremost in importance among the facilities which must be designed and constructed to keep pace with this growth are the water storage reservoirs of the distribution system. The fire underwriters' recommendation that at least 3 days' supply of water be maintained in gravity storage provides a rough rule of thumb for the minimum required reservoir capacity at any particular stage of the system's development. When additional storage capacity becomes necessary, the water works operator must decide which type of reservoir will best suit the needs of his community.

Basically there are four types of distribution reservoirs which may be considered: [1] steel tank reservoirs, [2] reinforced concrete reservoirs below ground level, [3] reinforced concrete reservoirs above ground level, and [4] reservoirs formed by impounding water behind a dam.

Steel Tank Construction

The typical steel tank reservoir of today is an all-welded, vertically cylindrical structure consisting of a comparatively thin steel plate floor to which is directly welded the first course of vertical wall steel. The tank wall is made up of circumferential courses graduated uniformly in thickness from the thicker bottom course—so designed as to withstand with an ample factor of safety the hoop tension caused by the maximum water load in the tank—to a minimum thickness of ¼ in. in the top course. Steel columns and girders form a support for a radial rafter system, which, in turn, supports a steel plate roof deck. As an alternative, the steel column and girder system is used to support a timber rafter system on which is laid a wood roof deck with composition roofing.

The interior steel surfaces of the tank must be protected against corrosion with some type of coating, unless the cathodic type of protection is employed for all submerged surfaces. Even then it is still necessary to protect from rusting all steel surfaces above the average water line. The exterior of the tank is generally painted with red lead and aluminum, not only for protection against the elements, but also to hold down the temperature of the stored water.

The tank is usually laid on a prepared sand or rock base, which should be well drained to prevent settlement. Sometimes a small earth dam is thrown up around the tank, and oil is forced under pressure into the base through a previously installed system of conductor pipes. The purpose of this oil-saturated base, of course, is to prevent soil corrosion of the bottom plates. A more expensive method of corrosion control, but probably more reliable, is to jack up the tub on cribbing approximately 36 in. above the ground after the bottom plates and first course of vertical steel have been assembled. Then, after a water leakage test has been made, the underside of the bottom plates is sand blasted and a protective coating applied. The tub can then be lowered to its final grade, generally on an oiled-sand base.

Concrete Reservoir Construction

Concrete reservoirs below ground level are usually constructed by grading out a basin having a comparatively flat floor and sloping sides, and by placing over it a reinforced concrete slab. Thorough earth compaction of the subgrade is required in advance of pouring the concrete to insure against subsequent slab settlement with accompanying water leakage. It is generally thought advisable to provide a system of expansion joints in the slabs to prevent undesirable cracking, and various mastic and rubber materials are used to seal them. A system of tile sub-drains laid in gravel, and in close proximity to the expansion joints, is usually necessary to collect and carry away any leakage.

Sometimes these reservoirs are left uncovered, but more often a roof structure is provided which consists of timber or steel columns and girders supporting a corrugated metal roof or a wood roof deck covered with composition roofing. Several cities in Southern California, within the last few years, have constructed this type of reservoir but with a reinforced concrete roof slab supported on concrete columns. A blanket of earth approximately 24 in. thick was then placed on the slab and the entire top of the reservoir landscaped.

An essential requirement in this type of construction is absolute water-tightness in the roof slab and its expansion joints, to prevent possible contamination of the water supply due to irrigation of the earth above.

Reinforced concrete reservoirs constructed above ground level are of two classes, nonprestressed and prestressed. The nonprestressed type has been in use for many years in all parts of the country. In its rectangular form, it consists of a reinforced concrete floor slab and a vertical outside wall which is designed as a cantilever type of retaining wall. In its circular form, the outside wall is designed to resist the hoop tension forces applied by the water load. In either form, it is the usual practice to provide expansion joints in the floor slab, particularly where the floor joins the vertical wall section. Here, also, a system of tile subdrains is employed to carry away any leakage through the expansion joints.

This type of reservoir, in the circular form with no prestressing, may develop cracks in the walls after the tank is filled. This results in leaks and unsightly stains on the exterior surface of the reservoir. When the horizontal reinforcing steel in the vertical wall is stressed in hoop tension, the rods tend to stretch slightly, cracking the concrete, which has very little ability to take tension. The opening up of these cracks is more pronounced in

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ALAMITOS RESERVOIR, multiple steel tank reservoir, total capacity 60 million gallons.
On Signal Hill, Long Beach, Calif., six miles across the city from J. Will Johnson Reservoir.

relatively deep reservoirs, where the water pressure is greater.

In the modern prestressed concrete tank, the vertical wall is wrapped spirally from the bottom to the top with a high-tensile-strength wire under sufficient tension to hold the concrete in compression even after the tank is filled. The wire wrap is covered with a coating of gunite to protect it from corrosion.

It is also common practice to install in the wall section uniformly spaced vertical rods which have been threaded at the top and provided with nuts that can be screwed down against the top of the tank wall, placing the rods in tension. These highly stressed rods, anchored into the base of the wall and installed without bond to the concrete throughout their length, place the wall in vertical compression. As the concrete is held constantly in compression, even with the maximum water load applied, it is impossible for cracks to open up.

Reservoir Site

The formation of a distribution reservoir by impounding water behind a dam is dependent upon the availability of a suitable canyon located within a reasonable distance from the area to be served. Furthermore, the canyon must be of such shape and geological formation that the required storage capacity can be obtained by the construction of a dam which is both economical and safe.

To provide adequate service and maximum fire protection, all four types of reservoirs must be located on sufficiently high ground to provide a normal gravity pressure of 50-90 psi in the distribution system. If the community is so unfortunate as to have no elevated reservoir sites, it must depend upon available sources of power for pumping to create water pressure. The potential danger of having no water pressure with which to fight fires during periods of power outage cannot be minimized. It can be partially offset, however, by having auxiliary power available, or by having one or more elevated storage tanks ready to serve an emergency supply when needed.

Having considered the various types of reservoirs, the water works operator must next determine, by a comparison of the merits of each, which type will best suit his needs. The comparison may be made on the basis of water-tightness, flexibility of operation, appearance, safety, vulnerability, maintenance, and cost.

Watertightness

The modern all-welded steel tank reservoir is permanently watertight and unaffected by climatic changes. There is no need for a subdrain system to carry away anticipated leakage, such as is necessary with reinforced concrete reservoirs. This solves a particularly troublesome maintenance problem, for leaks through hundreds and, in some reservoirs, thousands, of feet of expansion joints are often exceedingly difficult to locate and correct. Furthermore, in a concrete reservoir, if leakage is allowed to persist it is almost certain to carry away soil material from beneath the floor slabs, creating voids which could lead to serious structural problems. Although leakage is probably not so great in shallow reservoirs (up to 12-15 ft. in depth), it is often a serious and perplexing job to keep the deeper reservoirs (15-25 ft. in depth) watertight because of the comparatively higher water pressure. All water works engineers are familiar with the leakage problems encountered in the unlined basins behind dams.

The steel tank, therefore, is the only reservoir structure in which the water works operator can be positive of watertightness, immediately after construction and throughout its life,

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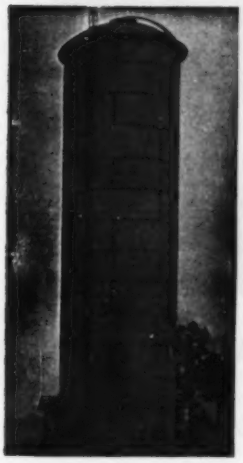

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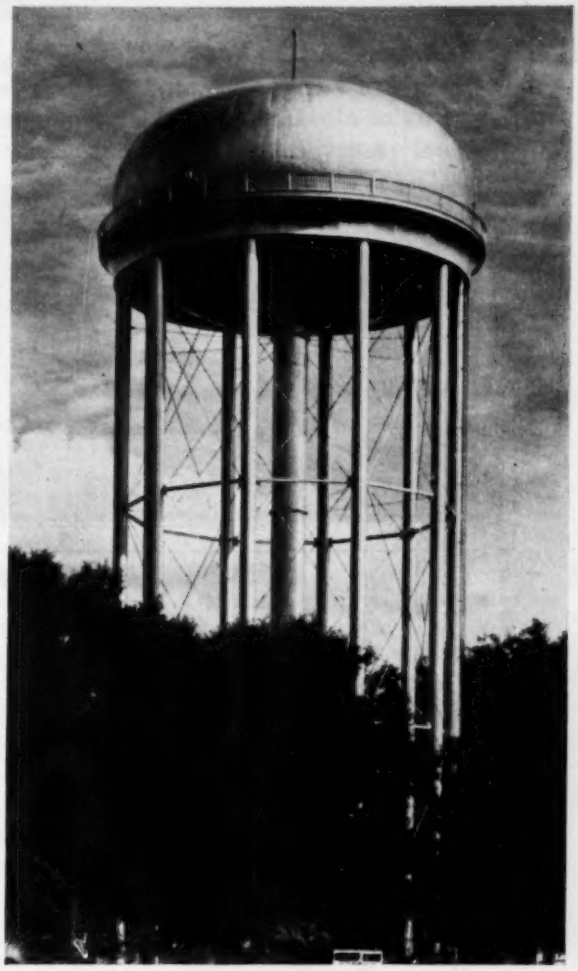

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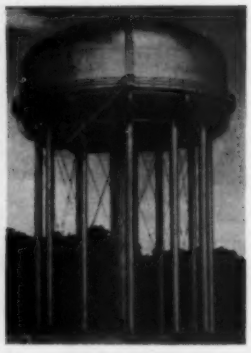
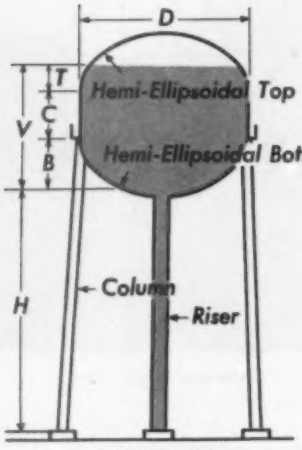
Capacities and Sizes of

STANDARD ELEVATED STEEL TANKS

by PITTSBURGH · DES MOINES

In these compact but complete tables, data are furnished on the various types of elevated steel tanks, and on steel reservoirs. For full information as to the application of these tanks, for designs, for specifications, or for estimates, write—without obligation to our nearest office.





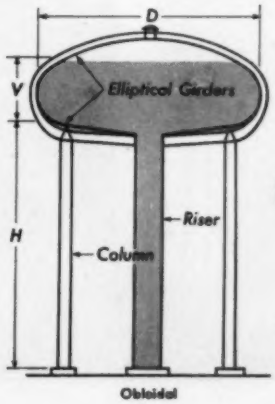
Double Ellipsoidal

TABLE I—DOUBLE ELLIPSOIDAL TANKS

Capacity U.S. Gallons	Tank Dimensions D	V	B	C	T	Balcony Width	Number of Columns	Radial Bevel of Columns	Tower Height H
25,000	18'0"	14'4⅜"	4'9"	6'0¼"	3'7⅛"	24"	4	1:12	see note**
30,000	18'0"	17'0"	4'9"	8'7¾"	3'7⅛"	"	"	"	"
40,000	20'0"	18'6⅝"	5'2⅜"	9'4⅛"	4'0"	"	"	"	"
50,000	22'0"	19'2½"	5'11"	8'10⅜"	4'4⅜"	"	"	"	"
50,000	24'0"	16'8⅛"	6'4⅛"	5'6⅜"	4'9⅝"	"	"	"	"
60,000	24'0"	19'7½"	6'4⅛"	8'5⅜"	4'9⅝"	"	"	"	"
75,000	26'0"	21'2⅛"	6'10½"	9'1⅛"	5'2⅜"	"	"	"	"
100,000	28'0"	23'8¾"	8'7"	9'6½"	5'7⅛"	"	"	"	"
100,000	30'0"	21'0⅞"	8'11"	6'1⅞"	6'0"	"	"	"	"
150,000	32'0"	27'4"	9'4⅛"	11'7"	6'4⅜"	"	"	"	"
150,000	34'0"	24'9¾"	9'10½"	8'1⅜"	6'9⅝"	"	"	"	"
200,000	36'0"	29'4½"	10'6⅛"	11'8"	7'2⅜"	"	"	"	"
250,000	38'0"	33'0"	11'3⅜"	14'3¾"	7'4⅞"	30"	6	1:20	"
250,000	40'0"	30'10½"	11'10½"	8'6"	10'6"	"	"	"	"
300,000	44'0"	30'9"	13'0⅛"	7'11⅜"	9'8⅛"	"	"	"	"
400,000	48'0"	34'3⅜"	14'7"	11'0"	8'8⅜"	"	"	"	"
500,000	50'0"	39'0⅞"	15'6⅜"	15'5⅛"	8'0⅝"	"	8	"	"
500,000	55'0"	29'11"	12'0"	10'11"	7'0"	"	"	Vertical*	"
600,000	50'0"	45'10½"	15'6⅜"	22'3¼"	8'0⅝"	"	"	1:20	"
750,000	60'0"	41'7⅝"	18'0"	11'10⅜"	11'9"	"	"	Vertical*	"
750,000	65'0"	37'0⅜"	20'1⅞"	6'5"	10'5½"	"	"	"	"
1,000,000	65'0"	47'1¼"	20'1⅞"	16'5⅞"	10'5½"	"	10	"	"
1,000,000	70'0"	42'6½"	23'0"	10'9½"	8'9"	"	"	"	"
1,000,000	75'0"	35'0"	20'6"	8'6"	6'0"	"	"	"	"
1,250,000	70'0"	51'2⅜"	23'0"	19'5¾"	8'9"	"	12	"	"
1,500,000	70'0"	59'10⅞"	23'0"	28'1⅞"	8'9"	"	"	"	"

* Standard practice is to make columns vertical for Double Ellipsoidal Tanks whose diameter exceeds 50 ft. However, their columns may be inclined if desired, in which case their radial bevel would be 1:20.

** Standard tower heights (H) are as follows:
Up to 50 ft. in even 2 ft. intervals,
from 50 ft. to 100 ft. in even 5 ft. intervals,
and over 100 ft. in even 10 ft. intervals.
Most common standard tower heights are 75 ft. and 100 ft.



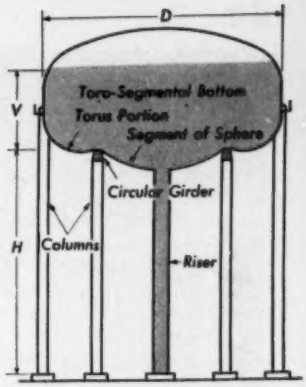
Obloidal

TABLE II—OBLOIDAL TANKS

CAPACITY U.S. GALLONS	DIAMETER D	HEAD RANGE V	TOWER HEIGHT H
1,000,000	88' 0"	25' 0"	As Required
1,500,000	92' 0"	35' 0"	" "
2,000,000	106' 0"	35' 0"	" "

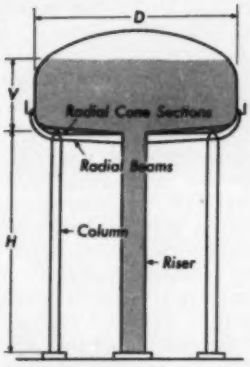
TABLE III—TORO-SEGMENTAL BOTTOM TANKS

CAPACITY U.S. GALLONS	STANDARD HEAD RANGES V			TOWER HEIGHT H
750,000	25′ 0″			As Required
1,000,000	25′ 0″	30′ 0″	35′ 0″	" "
1,500,000	25′ 0″	30′ 0″	35′ 0″	" "
2,000,000		30′ 0″	35′ 0″	" "
2,500,000		30′ 0″	35′ 0″	" "
3,000,000		30′ 0″	35′ 0″	" "



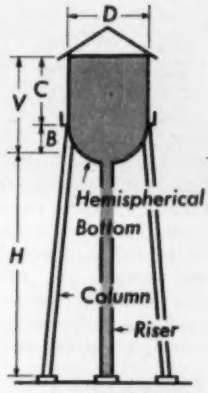
Toro-Segmental

TABLE IV—RADIAL CONE BOTTOM TANKS



Radial Cone

CAPACITY U.S. GALLONS	TANK DIMENSIONS D	V	NUMBER OF COLUMNS	TOWER HEIGHT H
300,000	53′ 0″	20′ 0″	8	As Required
500,000	60′ 0″	25′ 0″	"	" "
750,000	73′ 0″	25′ 0″	"	" "
750,000	67′ 0″	30′ 0″	"	" "
1,000,000	85′ 0″	25′ 0″	10	" "
1,000,000	77′ 0″	30′ 0″	"	" "
1,000,000	71′ 0″	35′ 0″	"	" "
1,250,000	95′ 0″	25′ 0″	12	" "
1,250,000	87′ 0″	30′ 0″	"	" "
1,250,000	80′ 0″	35′ 0″	"	" "
1,250,000	74′ 0″	40′ 0″	"	" "
1,500,000	103′ 6″	25′ 0″	"	" "
1,500,000	95′ 0″	30′ 0″	"	" "
1,500,000	88′ 0″	35′ 0″	"	" "
1,500,000	81′ 6″	40′ 0″	"	" "
2,000,000	108′ 6″	30′ 0″	16	" "
2,000,000	101′ 0″	35′ 0″	"	" "
2,000,000	94′ 0″	40′ 0″	"	" "
2,500,000	121′ 6″	30′ 0″	"	" "
2,500,000	112′ 0″	35′ 0″	"	" "
2,500,000	105′ 0″	40′ 0″	"	" "
3,000,000	123′ 6″	35′ 0″	20	" "



Hemispherical Bottom

TABLE V—HEMISPHERICAL BOTTOM TANKS

Capacity in U.S. Gallons	Tank Dimensions D	V	B	C*	No.** of Columns	Balcony Width	Tower height from foundation top level to bottom capacity level of tank (H)††						
5,000	9′0″	11′ 0⅜″	1′2½″†	9′ 9⅞″	4	None	31′ 9″	38′3″	51′9″	58′9″	72′9″	79′9″	93′ 9″	100′ 9″
10,000	13′0″	11′ 7¾″	6′0″	5′ 7¾″	4	None	30′ 0″	40′0″	50′0″	60′0″	70′0″	80′0″	90′ 0″	100′ 0″
15,000	13′0″	16′10¾″	6′0″	10′10¾″	4	None	30′ 0″	40′0″	50′0″	60′0″	70′0″	80′0″	90′ 0″	100′ 0″
20,000	13′0″	21′ 8″	6′0″	15′ 8″	4	None	30′ 0″	40′0″	50′0″	60′0″	70′0″	80′0″	90′ 0″	100′ 0″
25,000	15′0″	19′10½″	5′4″	14′ 6½″	4	18″	44′ 8″	50′0″	69′8″	75′0″	94′8″	100′0″	125′ 0″	
30,000	15′0″	23′ 8¼″	5′4″	18′ 4¼″	4	18″	44′ 8″	50′0″	69′8″	75′0″	94′8″	100′0″	125′ 0″	
40,000	17′0″	24′11¼″	6′8″	18′ 3¼″	4	24″	46′ 3″			75′0″	96′3″	100′0″	125′ 0″	
50,000	19′0″	25′ 6″	8′0″	17′ 6″	4	24″	55′ 0″	63′4″	75′0″	83′4″	91′8″	100′0″	120′ 0″	140′ 0″
60,000	19′0″	30′ 3½″	8′0″	22′ 3½″	4	24″	55′ 0″	63′4″	75′0″	83′4″	91′8″	100′0″	120′ 0″	140′ 0″
75,000	21′0″	30′ 6¼″	8′0″	22′ 6¼″	4	24″	55′ 0″	63′4″	75′0″	83′4″	91′8″	100′0″	120′ 0″	140′ 0″
100,000	24′0″	30′11¾″	8′6″	22′ 5¾″	4	24″	50′ 0″	63′1″	75′0″	79′7″	91′6″	100′0″	116′ 6″	141′ 6″
150,000	28′0″	34′ 5⅞″	10′5″	24′ 0⅞″	4	30″	54′10″	63′2″	75′0″	83′4″	91′8″	100′0″	120′ 2″	140′ 3″
200,000	32′0″	35′11½″	12′9″	23′ 2½″	6	24″	54′ 1″	62′5″	75′0″	83′4″	91′8″	100′0″	120′11″	141′10″

* This column lists height of tank cylinder up to high water level. The cylinder actually extends 3″ higher.
† The bottom of this 5000 gallon tank is a segment of a 9 ft. radius sphere.
** Radial bevel of columns of 4 column towers is $1\text{-}11/16$:12; of 6 column towers 1:10.
†† Towers at heights other than those listed are available.

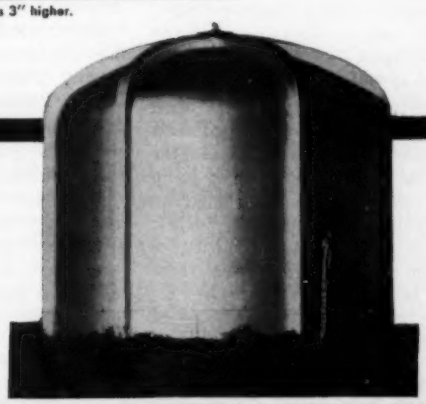


TABLE VI—STEEL RESERVOIRS

Capacity in U. S. Gallons	Diameter	Height
50,000	20′	21′ 6″
60,000	22′	21′ 6″
75,000	24′	22′ 6″
100,000	26′	25′ 6″
150,000	30′	28′ 9″
200,000	34′	29′ 9″
250,000	38′	29′ 9″
300,000	42′	29′ 3″
400,000	46′	32′ 6″
500,000	50′	34′ 6″
750,000	60′	35′ 9″
1,000,000	70′	35′ 0″
1,500,000	80′	40′ 3″
2,000,000	95′	38′ 3″
2,500,000	110′	35′ 6″
3,000,000	120′	35′ 9″
4,000,000	130′	40′ 9″

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provided, of course, that ordinary precautions are taken continuously to protect the steel from corrosion.

Flexibility of Operation

From the standpoint of continuity of service, flexibility of operation should be considered when planning any reservoir. For example, it is exceedingly desirable to be able to close off one portion of a reservoir for cleaning or other maintenance work while continuing to serve the distribution system from the other portion. A basin behind a dam would have no such provision ordinarily, but it is common practice in concrete reservoirs below ground level, and in rectangular reservoirs above ground level, to provide bulkhead walls which divide the reservoir into two or more sections. This flexibility of operation can be obtained with both steel and concrete tanks by constructing a reservoir made up of two or more tanks.

A multiple-tank reservoir gives the community added protection by making it possible to hold full tanks out of service for emergency use. With this provision, if a major main break in the distribution system should quickly empty the reservoir tanks in use, the emergency supply in the full tanks could be cut in after the break has been isolated. In this respect, the advantages of a multiple-tank reservoir cannot be stressed too strongly.

Appearance

With the possible exception of a reservoir lake formed behind a dam, there is little question that the concrete reservoir buried below ground level and landscaped on top is the most attractive type aesthetically. In recent years, however, water works men have endeavored to dress up the above-ground reservoir. The prestressed concrete tank has been constructed with a dome roof and center cupola and with a pilaster effect on the sides. These ideas have also been carried out with success on steel tanks. True enough, hollow pilasters on steel tanks have no function except possibly to house overflows and access ladders, but they do break up the large, plain surfaces of the shell and make the structure look less like an oil storage tank. Obviously, the architectural treatment is more necessary in a residential district than it would be in an industrial area.

Safety

Aside from enemy bombing, the greatest hazards to which reservoir structures are exposed are earthquakes, land subsidence, and foundation settlement. If a community is to have a safe and dependable water supply, its reservoirs must be adequately designed to withstand these superimposed forces.

In recent years many localities in California have been subjected to rather severe earth shocks with resulting damage to the water system. In addition, some areas of the state have been experiencing verying degrees of land subsidence. The magnitude of this settlement, particularly in the oil-producing communities, has assumed alarming proportions. For example, in Long Beach, the subsidence ranges up to 2 ft. on Signal Hill and up to 17 ft. in the harbor area. Similar effects have been noted in Santa Fe Springs, another oil-producing community. Engineers are now in general agreement that this subsidence is largely due to the extraction of oil and gas.

In the harbor district of Long Beach, the effect of subsidence on subsurface facilities is particularly severe, resulting in many pipeline breaks and other structural failures. Differential subsidence is also causing the larger surface structures to tilt appreciably, owing to greater settlement on one side of the structure than on the other. Foundation settlement can also cause severe stresses in reservoirs. One of the fundamental weaknesses of the aboveground concrete reservoir is its inability to withstand settlement. The bottom of a prestressed concrete tank is usually only 3-4 in. thick, is not heavily reinforced, and possesses very little flexibility. On the other hand, the bottom of a steel tank is a flexible member, capable of accommodating itself to considerable surface settlement without becoming overstressed.

The difficulties of designing a large concrete reservoir, either above or below ground level, capable of withstanding these sometimes enormous, unpredictable forces, can be easily appreciated. One safe solution to the problem seems to be the construction of a multiple steel tank reservoir, each unit of which is free to move independently of the others and is sufficiently flexible to accommodate itself to changing foundation conditions or to applied external forces.

Vulnerability to Bombing

The vulnerability of water supply reservoirs to enemy attack is a subject frequently discussed by water works men. The construction of a reservoir capable of withstanding enemy bombing would ordinarily be prohibitive in cost. During the last war many communities resorted to the camouflaging of tanks and covered reservoirs with special paint, but the effectiveness of this method under actual attack is questionable. Without doubt, the buried reservoir, hidden beneath a park or other landscaping, is far less exposed to enemy bombing raids than all other types of reservoirs. The enemy may have access to maps of the region, however, and can spot a park or other distinguishing terrain known to overline a reservoir just as easily as sighting an exposed tank on a hill.

It is possible that under enemy bombing the steel tank with its greater ability to absorb shock waves would hold up better than a concrete reservoir, which would tend to shatter. Unfortunately, all reservoirs are more or less vulnerable to enemy action. For this reason, it is well for a community to have two or more reservoirs located at widely separated points.

Maintenance

A comparison of the various types of reservoirs would be incomplete without some consideration of the subject of maintenance. The open reservoir behind a dam requires considerable maintenance to control the various growths which persist at the water's edge, both above and below the water line. If the dam is of concrete, there are sure to be problems of unexpected cracking, settlement or other movement, and spalling of concrete, all of which require attention.

The concrete reservoir, either above or below ground level, also has its maintenance expense. There is ample evidence to indicate that concrete tanks give trouble at the juncture between the vertical wall and the floor slab. An article[1] published in 1949 pointed out that the constant "breathing" motion of the walls as the water level fluctuates causes the ordinary seal to leak to some extent. The article goes on to say that, if the leakage is greater than allowable, little can usually be done except to replace the joint material, perhaps with no resulting improvement. The rubber joint seal suggested in the article was developed after a prestressed tank, built along conventional lines, leaked so badly that a better type of seal became necessary. Prestressed tanks have frequently experienced trouble with the gunite coating on the reinforcement, which may spall off.

J. WILL JOHNSON RESERVOIR. Total capacity of these tanks is 40 million gallons.
Located on Dominguez Hill, Long Beach, Calif., diagonally across city from Alamitos Reservoir.

On the other hand, the modern all-welded steel tank, thoroughly leak tested during its construction, sand blasted, coated with coal-tar enamel on the inside, painted on the outside, and adequately protected on the bottom where it is in contact with grade, will have few maintenance problems. The only requirement throughout the years will be the maintenance of a protective coating on all steel surfaces. Experience has demonstrated that properly applied coal-tar enamel will last many years, and good-quality paint applied to the exterior of the tank should last 10-12 years before repainting is needed.

Cost

Reservoir costs vary widely, depending upon type, capacity, and local conditions. In a reservoir which is formed by impounding water behind a dam, there is no correlation between cost and capacity, the cost per million gallons being wholly dependent upon the good fortune of the community. If there is a large canyon of such shape and geological formation that a small, low-cost dam is all that is required, the cost per million gallons will be low. Conversely, if an expensive dam is required to impound a relatively small quantity of water, the cost per million gallons may be prohibitively high.

The cities in Southern California which have constructed large, underground reservoirs, landscaped on top and varying in capacity from 25 to 57 mil gal, found that the cost ranged from $21,000 to $28,000 per million gallons.

Steel tanks with capacities of 1-10 mil gal vary in cost from $28,000 to $38,000 per million gallons, depending upon the design and type of roof. Prestressed concrete tanks, the chief competitors of steel tanks, have been running erratically from 10 to 60 per cent higher than steel. In multiple steel tank reservoirs consisting of six to twelve tanks of 3-4-mil gal capacity each, the cost has been running from approximately $26,000 to $29,000 per million gallons.

As steel tanks can be built to 90 ft. in height, or more, their construction permits a more economical use of land than do concrete tanks, the practical height limit of which is usually 35 ft.

Long Beach Experience

It must be apparent that the author is somewhat partial to steel tank reservoirs. This preference is the result of 20 years' experience with steel tanks at Long Beach, and it might, therefore, be appropriate to conclude this paper with an account of this experience.

In 1931 Long Beach had one small concrete reservoir, barely providing storage for a 3-hour normal demand. The author's first assignment with the Long Beach Water Dept. was to assist a firm of consulting engineers in designing a 20-mil gal reservoir to be constructed on Alamitos Hill, which is a part of an area called Signal Hill.

It was tentatively planned to construct six large concrete tanks, arranged in two rows of three tanks each, placed close together and connected with flexible steel plates at their near sides in such a manner that the spaces between the tanks could also be utilized for water storage. The resulting structure would have been an eight-cell reinforced concrete reservoir, approximately 26 ft. in height, resting on a graded portion of Alamitos Hill. Before the plans were completed, however, a surveying party, which had been running a precise-level survey over the Signal Hill area, determined that up to 6 in. of subsidence had taken place in the 5-year period preceding 1931.

This disclosure caused considerable apprehension in the minds of the consultants about the structural

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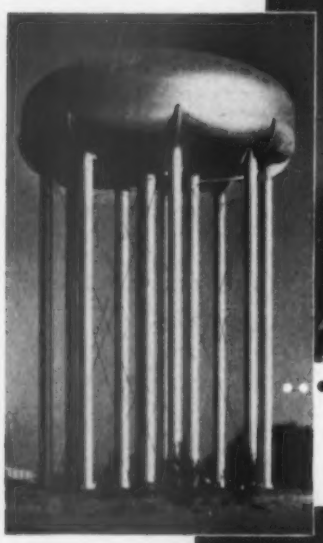
The smooth, streamlined Watersphere presents a pleasing appearance. All piping connections and ladders are located inside the supporting column to which access is provided by a door at ground level. The lower portion of the supporting column may also be used as a pumphouse.

Capacity in Gallons	Diameter of Sphere
25,000	19'4"
30,000	20'4"
40,000	22'4"
50,000	24'0"
60,000	25'6"
75,000	27'4"
100,000	30'0"
150,000	34'0"
200,000	37'6"
250,000	40'6"



ELLIPSOIDAL-BOTTOM WATER TANKS

Ellipsoidal-bottom elevated tanks are relatively large diameter and shallow depth. Unless otherwise specified, they are built with cylindrical columns and ellipsoidal roofs.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
50,000	22'0"	19'0"
60,000	24'0"	19'0"
75,000	26'0"	21'0"
100,000	28'0"	24'0"
125,000	30'0"	25'6"
150,000	32'0"	27'6"
200,000	36'0"	29'6"
250,000	40'0"	29'0"
300,000	43'0"	30'0"
400,000	46'0"	35'0"
500,000	50'0"	37'6"

HORTONSPHEROIDAL WATER TANKS

Hortonspheroidal elevated tanks are modern, attractive structures. They are built in standard capacities of 1,000,000 to 3,000,000 gallons and are supported either on two rings of cylindrical columns or one ring of cylindrical columns and a large central riser.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
1,000,000	87'6"	25'
1,000,000	81'0"	30'
1,500,000	92'0"	35'
2,000,000	106'0"	35'
2,500,000	117'0"	35'
3,000,000	120'0"	40'

RADIAL-CONE BOTTOM WATER TANKS

A functional design that permits large capacity water tanks to be built with a relatively low range in head. They are pleasing in appearance and easy to maintain.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
500,000	60'4"	25'
750,000	74'3"	25'
750,000	67'6"	30'
1,000,000	86'0"	25'
1,000,000	78'0"	30'
1,000,000	71'6"	35'
1,500,000	104'0"	25'
1,500,000	96'0"	30'
1,500,000	88'0"	35'
2,000,000	112'0"	30'
2,000,000	102'0"	35'
2,500,000	114'0"	35'
3,000,000	117'0"	40'

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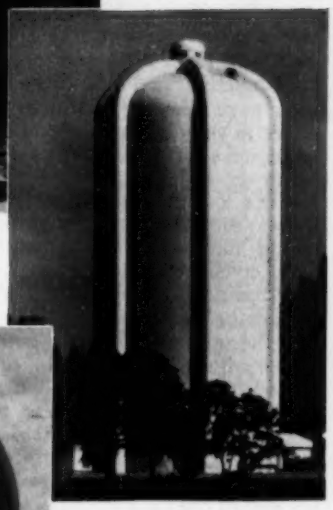
WELDED STEEL RESERVOIRS . . . . . .



Chicago Bridge & Iron Company builds welded steel reservoirs and standpipes in standard capacities up to 10,000,000 gals. Also in special designs similar to those shown in the views at the right. Our careful fabrication and erection methods assure a long service life. Welded construction resulting in smooth tank surfaces makes painting and maintenance easy and less costly.

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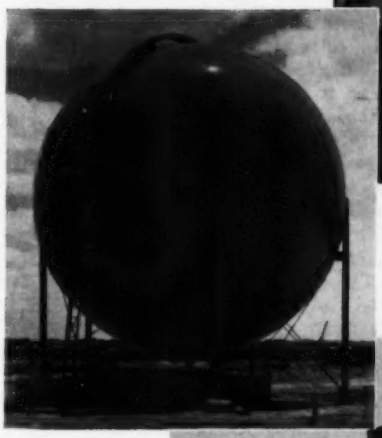

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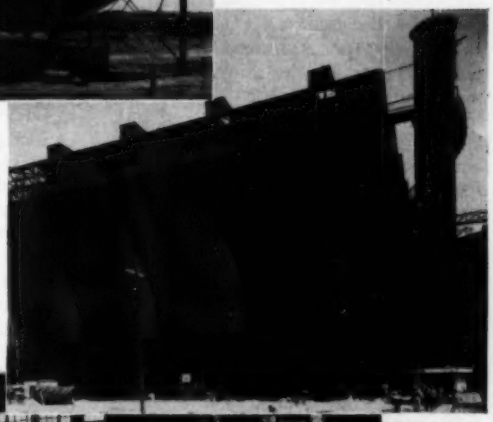

Our design, fabrication and erection departments have had years of experience in supplying water and sewage plants throughout the country with all types of heavy steel plate work. When requesting quotations on steel plate work, please send plans and specifications if they are available.

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safety of such a large concrete reservoir. After further study it was decided to construct a multiple steel tank reservoir, consisting of six tanks 132 ft. in diameter and 35 ft. in height. With each tank holding about 3.5 mil gal, the total capacity of the reservoir would be approximately 20 mil gal.

Completed in 1932, these tanks soon were destined to prove themselves in the disastrous Long Beach earthquake of Mar. 10, 1933. The reservoir rode the quake without damage, except to minor parts of the timber roof structure, in spite of a lateral motion of such magnitude that considerable water splashed over the rims of the tanks. The lack of damage was attributed to the fact that the upper rim of each tank had been equipped with ten ⅞-in. equally spaced radial rods, installed from the top of the central column to the angle iron placed around the rim and fitted with turnbuckles for tension adjustment. These rods held the upper rim of the tank round even when the water load was being thrown laterally by the force of the quake. In the Los Angeles area, one steel tank of comparable size, with an open top and no such radial rod reinforcement, was literally torn to pieces in the quake.

In 1936 the Alamitos Reservoir was enlarged by the addition of six more tanks of the same size, increasing the total storage to 40 mil gal. These tanks were equipped with 20 equally spaced radial rods instead of ten to provide additional earthquake resistance.

The first six tanks constructed at Alamitos Reservoir were coated on the inside with an enamel, consisting of a mixture of asphalt and coal tar, which eventually proved to be inferior, starting to break down after approximately 11 years of service. These tanks have since been successfully equipped with cathodic protection[2]. The second group of six tanks was coated on the inside with a 100 per cent coal-tar enamel which has given excellent protection for 16 years.

Built before welding became common practice, all twelve of these tanks are of riveted construction. The tubs, consisting of the floor and first ring of vertical steel, were assembled and riveted on cribbing above grade. The underside of the bottom plate was wire brushed and enameled before lowering the tube to an oiled-sand base. The exterior surfaces of the tanks were given two coats of red lead and a coat of aluminum.

In 1942, following the practice of many utilities, the tanks were painted olive-drab for camouflage purposes. This paint is still giving good protection after 10 years.

Profiting from 4 years' experience with the first group of six tanks, several improvements were made in the roofs of the second group. The improved roof consisted of a 2 x 10-in. creosote-treated Douglas fir rafter system supported on steel columns and girders. The rafters were covered with 1 x 6-in. tongue and groove redwood sheathing, on which was laid a built-up composition roofing.

Owing to the phenomenal growth of Long Beach during the war and post-war years, it became necessary in 1950 again to increase the total reservoir capacity. In the interest of decentralization, it was decided to place a portion of this additional storage on Dominguez Hill, approximately 6 miles to the northwest of Alamitos Reservoir. This area, being oil-producing, presented the same possibility of future subsidence as the Alamitos Reservoir site but was the only other high ground available.

After much deliberation in which many factors were considered, including the continued subsidence of the Signal Hill area, the possibility of settlement at the proposed site, the general seismic activity of the entire area, the ever-present possibility that the excessive subsidence in the harbor district might act as a trigger to set off further earth movements, and the exceptionally low-cost service record of the existing twelve tanks, it was decided to add six tanks at Alamitos Reservoir and to construct twelve more steel tanks of the same size and at the same elevation on Dominguez Hill. This would provide 60 mil gal of storage at Alamitos Reservoir and 40 mil gal at Dominguez Hill.

When completed, all eighteen of these new steel tanks were identical in construction, incorporating the points of design which the previous 20 years' experience had dictated. Of all-welded construction, the bottom plates and first ring of vertical steel were assembled and welded on grade. The tub was then jacked up on cribbing approximately 36 in. high and the second weld of the double-lap-welded bottom made. After the tub had been thoroughly leak tested by the vacuum method, the underside of the bottom was sand blasted, primed and coated with coal-tar enamel, and then lowered to its carefully prepared oiled-sand base.

The effectiveness of this tank bottom protection against corrosion was demonstrated when several exploration tunnels were dug beneath the existing tanks after 12 and 16 years of service. The bottom steel surface was found to be perfectly preserved and protected by the enamel, to which there still adhered a 1½-2-in. layer of oil-saturated sand.

Wood roof construction has been used chiefly because it is believed that corrosion cannot be definitely controlled on the underside of a steel roof deck, particularly where the deck rests upon the steel rafters.

Conclusion

Steel tanks show up exceedingly well when compared with other types of reservoirs. The modern steel tank is permanently watertight. It can be made attractive in appearance. It is comparatively safe against earthquake and other forces. It requires surprisingly little maintenance if ordinary precautions are taken to protect the steel surfaces from corrosion, and it is less expensive than most concrete reservoirs. These facts should impress all water works operators.

NOTE: *The reader's attention is called to the fact that this paper was written primarily on the basis of experience in a mild climate and in an area subject to earthquakes. Thus, the freezing factor is not considered at all and the factor of stress caused by earth movement is given more than normal weight.*—ED.

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2. Wells, C. Kenyon. Cathodic Protection of Steel Water Tanks. *Jour. AWWA*, 44:421 (May 1952).

Contents of Cylindrical Tanks

By W. F. SCHAPHORST
Mech. Engr., Newark, N.J.

FIGURING the gallons in a vertical cylindrical tank takes time, and errors are often made in longhand figuring. The accompanying chart quickly gives the number of gallons in a vertical tank of this kind, of ordinary size, and even beyond the ordinary sizes.

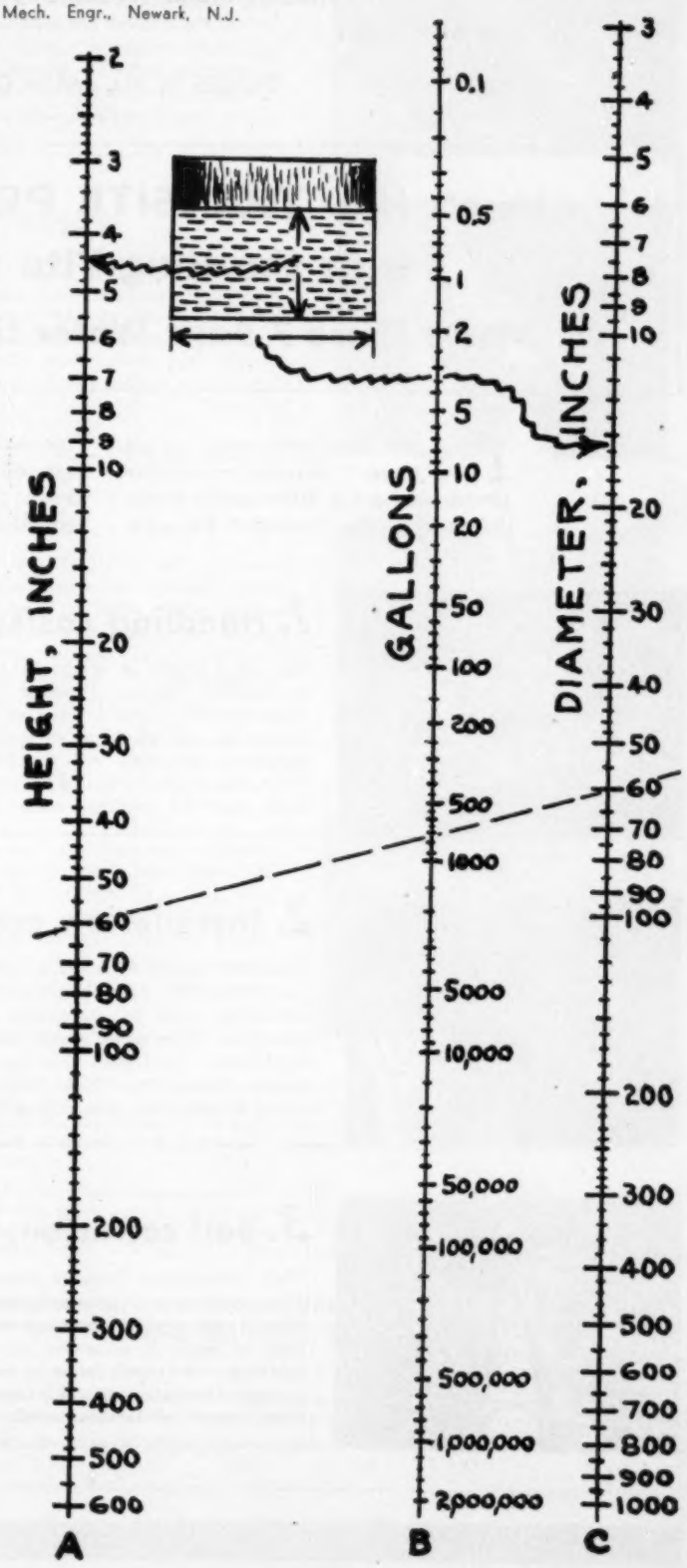
For example, how many gallons will be held by a cylindrical tank 60″ high by 60″ in diameter? The dotted line drawn across the chart shows how it is done. Connect the 60 in the height column (A) with the 60 in the diameter column (C) and the answer is shown in the volume column (B) to be very close to 740 gallons. Figure it out in longhand or on a slide rule and you will find that the answer is 733 gallons, showing that the chart is sufficiently accurate for general use over a wide range of tank sizes.

Inversely the chart may be used to figure the size of tank that will hold a certain number of predetermined gallons. Thus if a tank is wanted to hold 740 gallons, simply run any straight line through the 740 in column (B) and the intersection with column (A) gives the height, and the intersection of the same line with column (C) gives the diameter. By swinging a straight line around the desired point in column (B) the most economical height and diameter combination is readily obtained. As will be observed, there are hundreds and thousands of combinations possible to hold 740 gallons. Also, if we should have a tank 60″ in diameter and, say, 200″ high, and it should be desired to pour only 740 gallons into it, the same dotted line drawn across this chart will show that by filling the tank to a height of 60″ it will contain 740 gallons.

The range of the chart, as will be observed, is very great. It will take care of any tank all the way from 2″ in height to 600″ in height, and any diameter from 3″ to 1000″. The maximum capacity of the largest tank is given as 2,000,000 gallons. The chart is based on the U.S. standard of 231 cubic inches per gallon.

Just as an "exercise," what, for instance, must be the dimensions of a tank (can) to hold exactly one gallon? Any line through the "one" in column (B) will give combinations of two dimensions—in fact hundreds of them. One of the combinations will be found to be 6″ high by 7″ in diameter. It will also be found that a flat-shaped tank (can) 3″ high by 10″ in diameter comes very close to having a capacity of one gallon. Or, if 20″ high by 4″ in diameter this combination will hold one gallon. The number of possible combinations is endless.

If the chart is used a few times you will keep it in a convenient place in your work desk.



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2. Installation costs:

Transite Pressure Pipe offers important economies that help combat increasing costs of water-line installation. It is quickly and easily assembled in the trench. The unique design of the Ring-Tite® Coupling allows installations to be successfully completed under adverse weather, temperature or terrain conditions. The job may be completed with a minimum of time and labor, thereby contributing important reductions in the overall cost of the system.

3. Soil corrosion:

Two factors give Transite Pressure Pipe exceptional resistance to corrosion: (1) the corrosion-resistant materials of which it is made; (2) the especially developed Johns-Manville process of manufacture which imparts a high degree of chemical stability to the finished pipe. This high resistance to corrosion has been substantiated by numerous installations. Many of these are serving as replacements in soils so destructive that the useful life of the pipe materials previously used had been seriously curtailed.

*Transite is a Johns-Manville registered trade mark

4. Internal corrosion:

Transite Pipe, because of its asbestos-cement composition, is not affected by tuberculation. Therefore, it is not necessary to resort to pipe of larger diameter to offset the internal effects of this costly form of pipe corrosion. And because progressive reduction of delivery due to tuberculation capacity is never a problem in a Transite pipe line, pressures and flows remain high—pumps operate at higher efficiencies. These factors are often reflected in better service and lower water rates in communities served by Transite lines.

5. Underground water losses:

To assure tight joints, Johns-Manville engineers developed the Ring-Tite Coupling for use with Transite Pressure Pipe. This efficient, factory-made coupling protects against pipeline failures resulting from leaky joints. The Ring-Tite Coupling consists of a Transite sleeve and two rubber rings. When assembled, each pipe end is encased firmly and securely in the Transite sleeve and sealed by the two rubber rings. These rings, in turn, are locked into grooves machined in the sleeve, resulting in a tight, yet flexible joint, and sealing against leakage.

6. Vibration and stresses:

Transite's flexible joints effectively absorb the vibration of heavy traffic—an especially important factor where pipe is laid under busy highways, or near railroad and street car tracks. Because each joint is capable of deflection up to five degrees, the entire line has a flexibility not ordinarily found in other types of waterline construction. This helps compensate for soil movements and other stresses to which the pipe may be subjected . . . provides an effective safeguard against costly pipe failures.

7. Maintenance:

In thousands of communities, Transite Pipe—with its advantages of joints that remain tight and flexible, its corrosion resistance, and immunity to tuberculation—provides low-cost water transportation that requires little, if any, maintenance. Transite lines do not have to be cleaned, lined, or replaced because tuberculation has reduced their original capacity. Reports from communities all over the country prove that Transite's asbestos-cement structure provides economies that continue through the years.

Plus

. . . the advantages of a complete, nationwide TRANSITE PIPE ORGANIZATION. The facilities of this organization include more than 250 field representatives with headquarters in 58 cities. It also comprises a staff of competent installation instructors who explain recommended installation practices to pipe-laying crews.

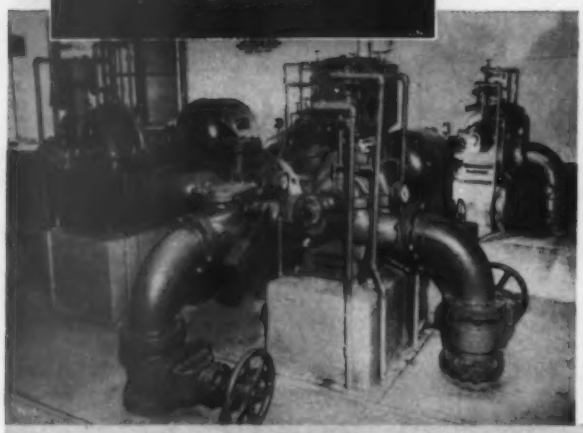
This J-M service is an important factor in helping to assure the installation economies as well as the long-term *overall* economies that go with Transite Pressure Pipe. The work of this field organization is a vital part of the helpful Transite Pipe service which J-M offers the water works industry.

STANDARD SIZES AND APPROXIMATE WEIGHTS OF TRANSITE PRESSURE PIPE

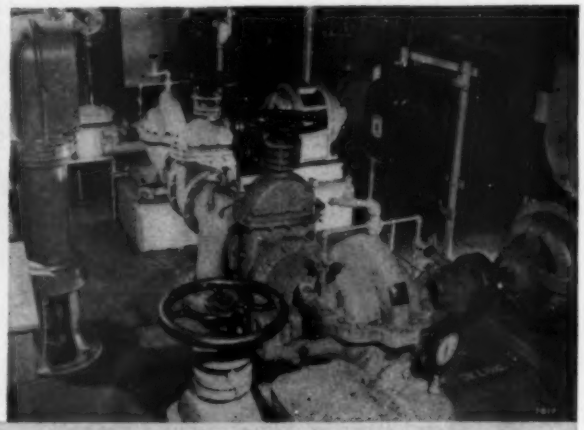
Class (maximum recommended working pressure, psi)	Equivalent head, feet of water	Nominal inside diameter, in.						
		4	6	8	10	12	14	16
		Pounds per linear foot including coupling and rubber rings						
150	346	7.6	13.0	19.8	31.9	43.3	57.7	72.5

DE LAVAL CENTRIFUGAL PUMPS

do a big job on the Jersey shore



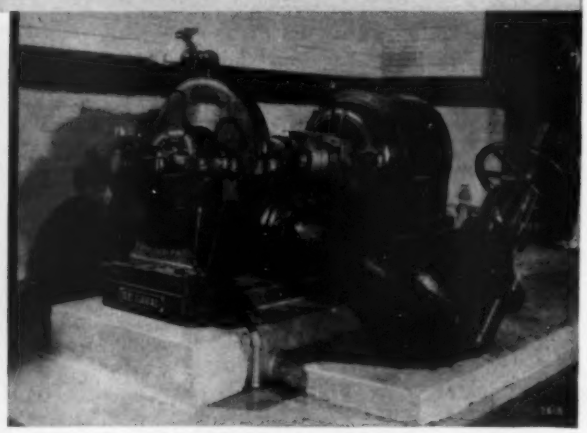
VENTNOR, N. J. These four De Laval Centrifugal Pumps are putting out 4,500 gpm and holding 46 lbs pressure over a 24-hour period. Installed in 1947 and 1948, they're still in the "infancy" of a long life of service.



MARGATE, N. J. This De Laval pump actually delivers 35% more than its rated capacity at peak demand periods. It is used as a booster from the reservoir to a 95-foot standpipe at sea level, to maintain a 40 lb plant pressure.

OCEAN CITY, N. J. The No. 2 and No. 3 De Laval pumps pictured here meet—with impressive ease—a 3,600,000 gallon per day water requirement at the main Tenth Street pumping station at 46 lbs pressure. No. 1, not shown, is a million-gallon De Laval unit installed in 1950.

WILDWOOD, N. J. In use since 1938, this 1,040 gpm De Laval pump, with a head of 138 feet, maintains a constant level in the tank for continuous supply into the mains at 45 lbs pressure. The reservoir for this plant has a total capacity of 5,200,000 gallons.



ON THE JERSEY SHORE as in just about every other part of the country, De Laval pumps play a big part in meeting the ever increasing water requirements of growing communities. De Laval's lower capacity units, ranging from 100 thousand gallons per day, offer the same, rugged durability as their big brothers rated at 100 million gallons per day and up. Ask your De Laval representative for complete data.

See us IN BOOTH 58 at the show in Seattle

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY

Nottingham Way, Trenton 2, New Jersey

DL 291

Centrifugal Pumps

Notes on Selection of Pumps and Checking Pump Efficiencies

By H. E. BECKWITH
Engineer, The Pitometer Company, New York, N. Y.

TODAY the great majority of pumping stations are equipped with electrically driven centrifugal pumps, with an occasional Diesel driven or turbine driven centrifugal installation. The old slow moving reciprocating pump of yesterday could always be depended upon to take care of changing pumping loads and varying heads without any great loss in efficiency. But, this is decidedly not so with the modern centrifugal pump, designed to work under rather fixed conditions. Any appreciable variation from these conditions is accompanied by a falling off in efficiency, which may be rather marked.

Unfortunately, the non-technical water works operator who got his early practical experience with the old displacement type of pump has not always become sufficiently acquainted with the characteristics of the centrifugal pump. Only too often the only demand made on a centrifugal pump is that it pump water, and little or no attention is paid to the efficiency with which it does its work. In fact the average water works man is usually not acquainted with any simple method of determining this efficiency.

It is, therefore, the purpose of this article to point out the conditions which may be expected to cause low operating efficiency, and to outline a simple method for testing the wire-to-water efficiency which gives results as close as is necessary in practical water works operation.

Basic Principles of the Centrifugal

As a youngster I used to tie a chestnut on the end of a string and whirl it around my head until I had imparted to it the force necessary to take it flying through the air at high speed. You did it, too. The principle of building up velocity of that chestnut by whirling it about the head is the same principle which is used in the design of a centrifugal pump. The water which enters the pump through the suction inlet is seized by the rotating vanes of the impeller and spun until it is rotating at terrific velocity. Since pressure and not velocity is desired, the pump is so designed that by gradually slowing down this velocity in the casing of the pump, the energy stored up in this rapidly moving water is almost entirely changed to pressure. The speed of the chestnut rests upon two factors—the length of the string and the number of revolutions made within a specified period of time. The speed, and hence the resulting pressure, imparted to water by a centrifugal pump also rests upon the same two factors—the diameter of the impeller and the number of revolutions per minute which the impeller makes.

There are, of course, practical limits to both the speed and the diameter so that it is not always possible to secure the full desired pressure with one pump. If not, the water is passed through two or more pumps in series, and each pump raises the pressure part of the total desired amount. Sometimes these two or more pumps are built in one pump case, in which instance each pump is called a "stage." Since electrically driven centrifugal pumps operate at fixed speeds, there is always one head under which a pump will operate most efficiently. Right here it will not hurt to repeat that any material deviation from this condition will result in decreased efficiency.

Pump Performance Curves

At this point I want to introduce a typical centrifugal pump curve which we will use for illustration during this discussion. Similar curves are available from the manufacturer for all medium sized and large pumps. On small pumps it is not customary to furnish such performance curves.

It will be noted from an inspection of the specimen curve that the greatest efficiency for this particular pump (about 75 per cent) is secured when the head is about 155 ft. and the discharge rate is about 1,300 gpm. You will also note that as the head is materially increased or decreased from the optimum head there is a large change in the pumping rate and a considerable drop in efficiency. A great deal has been done in design effort to widen out the "peak" of the efficiency curve into a "plateau" so as to give high efficiencies for centrifugal pumps under a wider range of operating conditions. Considerable progress has been made in this direction.

Friction Head—Its Importance

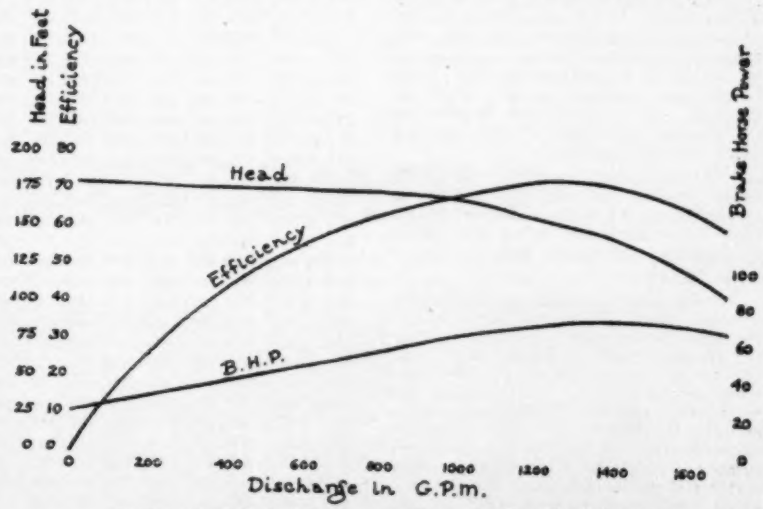
Let us see what happens when we forget to include pipe friction loss when figuring the total head against which the pump must operate. If we have figured on the pump whose curve we have, and if we are pumping through two miles of 16 in. main, the friction loss will add about 18 ft. to the pumping head—making it 173 ft. At this head (see curves) the pumping rate will drop to 1,000 gpm. and the efficiency to 70 per cent. Furthermore, the pump is operating on a very critical part of the curve where a slight increase in pumping head—caused by tuberculation in the main or by any other reason—would incur a precipitate drop in both the efficiency and the pumping rate. It also illustrates what can happen to a pump, after installation, when the pumping head has been increased above the head for which it was designed. As it is the nature of unlined iron and steel mains to tuberculate, resulting in a constantly rising friction loss, this is an important consideration.

Let us illustrate this in another way.

Selecting the Right Pump

Suppose that we are in the market for a 1,000 gpm. pump operating against a total head of 173 ft., and a pump whose curve we have been using has been submitted for consideration. I would not consider this pump a good "buy" to operate under these conditions. In the first place it will be noted that the efficiency of 70 per cent is much below the maximum efficiency of 75 per cent. But even more important, perhaps, is the fact that the pump at 173 ft. head is operating under "critical head" conditions. An increase of only about 8 ft. (less than 5 per cent) in the pumping head would bring the head to the maximum which the pump can create—in other words to the "cut off" point. This means that an increase in the head of only 8 ft. (about 3½ pounds) would decrease the pumping rate from 1,000 gpm. to zero gpm. Moreover an increase of only 3 ft. in head would cause a drop of 200 gpm. in the pumping rate. On the other hand, when we are working in the most efficient range of the pump a change of 3 ft. in the head would only cause a variation of 30 to 40 gpm. in the pumping rate; and, the efficiency is practically unaffected.

It follows, therefore, that one should buy a pump within the range where the efficiency curve is as *flat* as possible and the head curve is as *steep* as possible. In this connection a word of warning may not be amiss. By making the vertical scale of the



An Example of Typical Performance Curves for Centrifugal Pumps. Various designs show individual characteristics in respect to the curves produced.

Mr. Beckwith's article is based on a paper presented before the Penna. Water Operators Assn. and includes material from an earlier Reference and Data article by the author.

curve less than is customary, a much flatter *appearing* efficiency curve can be secured. So in comparing the performance curves of pumps be sure that they are plotted on comparable scales. I have known curves with reduced vertical scales to be submitted where I felt sure that the scale was deliberately reduced for the purpose of deception.

Mistaken Economy

Only too often in the revamping of a plant, efforts are made to re-use as much of the old equipment as possible. It may be assumed that if the old pump will handle 1,300 gpm. against 155 ft. of head it should have less trouble pumping the same amount from the river to the settling basin against a head of only forty or fifty feet. This is so. In fact, if we will look at the curve we will find it will pump more than 1,300 gpm. at the lower head. The curve does not go out that far, but it goes far enough to show what would happen—not only to the pumping rate but to the efficiency as well. The pumping *rate goes up* but the *efficiency goes down*—yes, way down. Reducing the head has a tendency to cause a pump to run away much as an automobile would run away down hill when the going becomes easier if the throttle were not closed to compensate for the decreased demand for power. This running away of the pump sometimes overloads the motor so that it runs hot. To prevent this, operators raise the head artificially by partly closing a valve on the outlet side of the pump. This decreases the load on the motor and brings the pumping rate back to normal. But it burns up a great deal of power needlessly as the closed valve destroys part of the head generated by the pump and only part of the work actually performed is effective. I have known of installations, such as this, where the installation of a new pump saved more than enough power in one year to pay the entire cost of the new pump and motor and also completely depreciate the old unit replaced.

But it is not always necessary to buy a new pump just because the head has been reduced. If we will get back to that chestnut on the string we will find that we can reduce the speed of the chestnut by reducing the length of the string, at the same time keeping the number of revolutions constant. In the same manner, we can cut down the pressure generated by a constant speed centrifugal pump by reducing the diameter of the runner. If the reduction in head is moderate, the manufacturer can advise you how much will have to be machined off the outside of the present impeller so that it will pump efficiently, or at a slight expense he will furnish a new impeller for the changed conditions. Or he may cut down your old impeller.

It is sometimes possible to secure a larger impeller to efficiently handle increased heads, but in this case the motor is likely to be overloaded unless the original specification anticipated such change as loads increased.

Another way to increase the speed of that chestnut would be to keep the length of the string constant and to increase the number of revolutions. It follows that if we increase the revolutions of any centrifugal pump we will increase the head which that pump will generate. This explains why a certain pump tested last fall gave a wire to water efficiency of only 40 per cent. This pump was designed for use with a gasoline motor and to operate under the then existing head conditions at a speed of 1400 rpm. Eventually electric power became available and the pump was connected to an electric motor and the speed increased to 1,800 rpm. This, of course, increased the head generated by the pump itself, and the efficiency was consequently very low.

A somewhat similar condition was found several years ago when a 5 mgd. installation designed to work against a head of 100 pounds was found to have been connected in series to a 5 mgd. pump designed to pump against 50 pounds pressure. This gave an installation with a design head of 150 pounds, but the actual head was still only about 100 pounds. The *output* was thereby *increased* to approximately 6 mgd. but the *efficiency decreased* to the point where it was only slightly above 40 per cent. New and properly designed equipment brought the wire-to-water efficiency up to about 75 per cent.

It can be readily seen from the above considerations that the chances of buying a suitable pump from the "junk man" are just about nil. It might be "as good as new" for the conditions for which it was designed and yet be absoluately worthless under any other conditions. In fact, it would probably be a most expensive liability. Yet pumps have been bought from the equivalent of "junk men", but most frequently have been "salvaged" by the original purchaser for other duty than originally purchased for.

So far, we have been discussing equipment which has been working under conditions which made it impossible to give a creditable showing. A mere inspection of the conditions and a knowledge of the design limitations would make it evident that satisfactory performance under these conditions could not be secured. However, there are occasions where, after installation, things happen to properly selected pumps which will cut the efficiency of the equipment. There was, for instance, the time when we found a water snake wrapped

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,007	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,272	300	1,061	350	910	400	796	450	707	500	636

World's Widest Range of Public Works Equipment

Milwaukee added 40 mgd to its pumping capacity by installing this 60 mgd Allis-Chalmers centrifugal unit in the space formerly occupied by one 20 mgd pumping engine. This new unit is driven by an Allis-Chalmers 3700 hp steam turbine and is also supplied with an A-C condenser.

Concurrent with the rise of America's great cities was the rapid expansion of American industry. These two closely interdependent forces gave impetus to each other as they forged mutual destinies. In 1847 the firm that became Allis-Chalmers operated a small factory in Milwaukee. Much of its earliest work was for the city . . . and as the years passed and the company grew, for other cities. Today Allis-Chalmers operates eleven plants in the U.S. employing 36,000 workers . . . offering over a thousand major products to large and small communities.

Today Allis-Chalmers can supply a major percentage of the equipment needed for sewage plants, water works, municipal power plants, street and highway construction, and other public works. See the three following pages for further information on A-C equipment.

The record of Allis-Chalmers in building centrifugal pumps speaks for itself. Of thousands built, no A-C centrifugal pump has ever failed to meet its guaranteed efficiency. This means that when you specify Allis-Chalmers you are getting exactly what you intended to buy . . . exactly what you need.

Hundreds of cities . . . large and small . . . are already profiting from the efficiencies of Allis-Chalmers pumps. The range of types and capacities of A-C pumps will meet the needs of any city. There are special pumps for water supply, fire protection, sewage, and drainage. Sizes range from small compact units handling only a few gpm to huge 72-inch pumps capable of handling three hundred thousand gpm.

Also worth while remembering is that you can get the entire pumping unit from Allis-Chalmers . . . for this company builds motors of every type, for operating every size of pump. You can also get the proper A-C starter for controlling the motor.

ALLIS-CHALMERS

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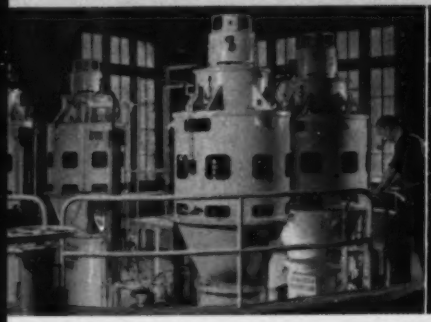
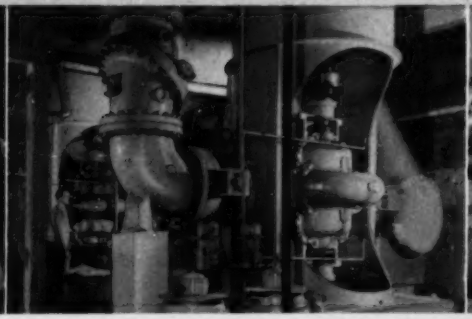
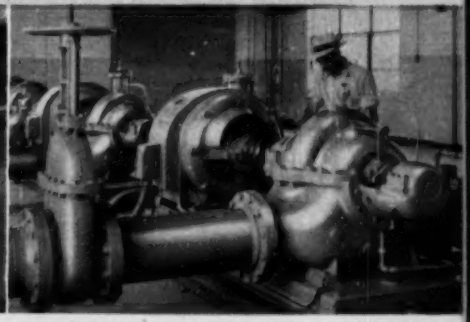
These 350 hp Allis-Chalmers synchronous motors drive A-C pumps in Gary water works.



These pumps are installed at a low level with motors mounted above to prevent flooding.



Allis-Chalmers 14 by 12-in. pumps and motors installed in a Texas pumping station



Relieve SEWAGE GROWING PAINS

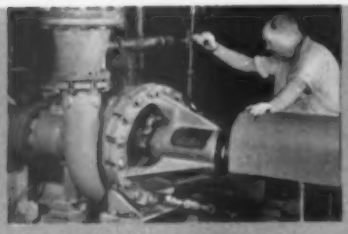
Demands on Sewage Facilities Become Acute with Population Growth

In every city the need for high efficiency, low maintenance sewage pumps is increasing as population grows. To meet this growing demand, Allis-Chalmers offers a wide range of sewage pumps engineered to the needs of municipalities.

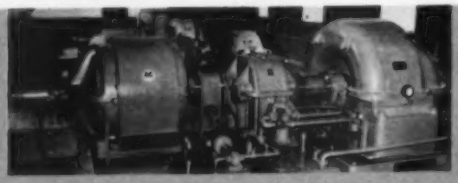
The Allis-Chalmers line is complete . . . pumps range in size from small compact units producing few gallons per minute to huge units capable of pumping many thousand gallons per minute. To meet installation requirements, pumps are available in both horizontal and vertical design.

As the world's largest manufacturer of public works equipment, Allis-Chalmers also offers an extensive line of motors, blowers, motor controls and allied equipment for modern sewage plant operation.

Whether you are planning expansion or modernization of your present sewage facilities, you can profit from Allis-Chalmers long experience in this field. For complete information call your nearest A-C sales office or write Allis-Chalmers, 1192 S. 70th St., Milwaukee 1, Wisconsin.



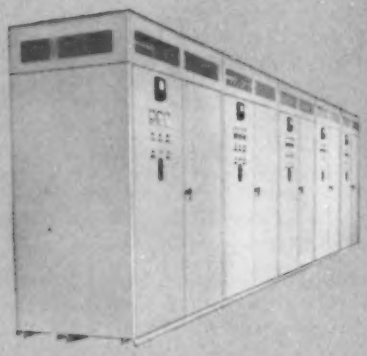
A-C SEWAGE PUMPS have wide impeller openings, rounded impeller inlets to pass solids freely.



BLOWERS—MOTORS Wide range of capacities and ratings for all sewage plant operation. Simple blower design assures maximum efficiency for all operations. Cast casing provides rigid, smooth operation. Available in pressure ranges from 1 to 6.50 lb, volumes to 35,000 cfm.

TYPE "SW" SEWAGE PUMPS: Single-stage, single suction type pump with volute casing design. Has non-clog impellers designed to pass maximum sphere sizes, rags, string and other materials for highest efficiency. Available in a wide range of capacities and heads. Adaptable to horizontal and vertical installation to meet requirements.

Right: Rear view of 3000 kva, 4160-2400 volt unit substation with both incoming line section and distribution feeder section consisting of metal-clad switchgear.



MOTOR CONTROLS: Dependable start-stop control for all sewage processing apparatus, in both single and grouped units. Simplified installation requires only connection to leads for operation. Expandable design permits easy addition of more cubicles when required.

Allis-Chalmers circuit breaker and power transformer are major components of this primary substation.

Electric Power Equipment

Allis-Chalmers can supply a major percentage of all power generation, and electrical control and distribution equipment for public works. Included in the power generation line are steam turbine generator units, surface condensers, condenser and boiler feed pumps, water conditioning service and equipment.

The range of electrical products includes all types and sizes of motors from 1 hp to 100,000 hp and up, and starters or control to suit every application.

Allis-Chalmers indoor and outdoor high and low voltage switchgear provides maximum protection and flexible control of power distribution circuits. All units are metal enclosed, factory built, so they need only be bolted in place and lines connected. Switchboards are custom built to fill your needs.

A-C builds a complete line of power and distribution transformers. Most sizes can be cooled with either oil or *Chlorextol* non-inflammable liquid, or they can be of the air-cooled type.

Load center, single circuit and multi-circuit unit substations are built in standard ratings to meet every application. They are completely factory built and can be installed adjacent to equipment being served.

Chlorextol is an Allis-Chalmers Trademark.

ALLIS-CHALMERS

1192 S. 70th St.
MILWAUKEE 1, WISCONSIN

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around the shaft with the result that the inlet ports were partially cut off and the suction lift increased way beyond the 15 feet maximum for best performance. In another and similar situation blocks of wood were found jammed in the ports. Then there was the time that low efficiency was caused by the blowing of the gasket of a multiple stage pump and the water was short circuiting back from a higher stage to a lower stage. One of our engineers once reported that an efficiency of 20 per cent was caused by the impeller slipping on the shaft.

Two interesting conditions have been found by the author which have no reference to the actual efficiency of the pumps but which were determined as the result of making efficiency tests. In one instance, where the meter through which power was purchased was used to measure the power input, it was found that an apparent low efficiency was caused by this meter being set 20 per cent high. In another instance, a pump was discharging into a closed distribution system. On the basis of the water *actually discharged* into the system (24-hour period) the pump had an efficiency of only 8 per cent. Had a standpipe or reservoir been floating on this system, the same amount of water could have been pumped with about one-eighth the amount of power which was actually used.

So much for the reasons why efficiency tests should be made at intervals.

A Simple Efficiency Test

The writer has worked out a simple method for making efficiency tests which he has been using with satisfactory results for some years.

At one foot of head and 100 per cent efficiency of *both pump and motor* it is theoretically possible to raise 318,200 gallons of water one foot with one kwh. To determine this theoretical value for any other head, simply divide 318,200 by the head involved. For instance,

$$\text{the value at 159 ft. would be } \frac{318{,}200}{159} = 2{,}001.2 \text{ gal.}$$

per kwh. In this connection the accompanying table may prove helpful in reducing calculations in pump testing.

To determine the *wire-to-water efficiency* of an installation it is only necessary to divide the actual pumpage per kwh by the theoretical value for the pumping head, as determined from the table. A rough check can be made by dividing the month's pumpage in gallons by the kwh consumed. This gives the gallons actually pumped per kwh.

Test Procedure

With the pump running, determine the total head in feet (including suction) against which the pump works. Divide 318,200 gallons by this total head (as above) to determine the theoretical 100 per cent pumpage per kwh. (Or take the figure from Table 1.) Next divide the actual gallons per kwh. by the theoretical gallons per kwh. to secure the wire to water efficiency.

To illustrate:

Assume a monthly pumpage of 32,640,000 gallons and a monthly power consumption of 30,200 kwh. Say the total head noted was 220 ft. Dividing 32,640,000 by 30,200 gives an actual pumpage of 1,081 gallons per kwh. Dividing 318,200 by 220 ft. gives a theoretical value of a possible 1,447 gallons per kwh at 100 per cent efficiency (see table). Then:

$$\frac{1{,}081 \text{ (observed)}}{1447 \text{ (theoretical)}} = 74.7\% \text{ overall}$$

wire to water efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or some other convenient period of time. During this period carefully check the output of the pump with any suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will funish the number of watts consumed for each revolution of the disk, and by counting its revolutions for ten or twenty minutes the rate of power input can be closely ascertained. Or the power company can be asked to measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, the latter method is the only feasible one for testing each unit separately.

Securing Total Head

The total head in feet must first be secured. If the pressure gauge reads in pounds, convert to feet by multiplying the pounds of pressure by 2.31 [feet of water head giving one pound gauge pressure]. The suction will probably be expressed in inches of mercury. Convert this to feet of water head by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the sum of the following:

Discharge pressure, in feet	xxx
Suction in feet	xx
Vertical distance pressure gauge is above point of suction measurement, feet	x
Total Head in feet	xxx

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump will be working against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical valve for the head against which the pump was operating. This gives the overall wire-to-water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

Power input to motor	90.0 K.W.
Rate of discharge	51,840 gal. per hr.
Delivery per KWH	576 gal.
Pressure	146 lb. = 337 ft.
Suction	15 in. = 17 ft.
Difference in gauge elevation	1 ft. = 1 ft.
Total head	355 ft.

Theoretical discharge 335 ft. head (see table) is $\left(\frac{318{,}200}{355}\right) = 897$ gal.

and

Overall efficiency (wire-to-water) is $\left(\frac{576}{897}\right) = 64\%$

If a suction gauge is not available, an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about two feet for loss in bends, etc.

What the Tests Reveal

Having shown the desirability of frequent tests and having presented a simple method for making them, it may now be interesting to discuss what these tests may be expected to show. In the first place, there have been great increases in the attainable efficiencies of centrifugal pumps within the past few years. Those of modern design may be expected to give up to the following overall (wire to water) efficiencies.

Capacity gpm.	Efficiencies Per cent
200	58
400	63
600	68
800	71
1000	73
1500	75
3000	80
5000	82
Over 5000	85

It will be noted that the larger the pump the higher the efficiencies.

There will be variations from these figures depending upon the head and other conditions. Such are submitted only for the purpose of giving something with which to compare the efficiencies of existing installations. This is important, because it will often be found that older equipment may have retained its original efficiency and yet be so inefficient in comparison with modern equipment, now available, that it is decidedly not economical to keep it in operation. It will be worth while to check the present efficiency of every centrifugal pump now more than ten years old, to determine how great a reduction in power consumption can be secured by replacement with more efficient modern pumps. You may be surprised.

If an old 1,000 gpm. pump, operating at an efficiency of 57 per cent is replaced with a new pump giving an overall efficiency of 73 per cent the same amount of water may be pumped with 22 per cent less power. This means that both the demand rate and the power consumption through each step of the existing rate schedule would be decreased 22 per cent. Such a reduction might prove enough to pay for the new installation in about one year's time. In order to get the gallons per kwh. to be expected at any head, for any efficiency, it is only necessary to determine theoretical gallons per kwh. for that head and then to multiply this theoretical value by the expected efficiency. If the total pumpage in gallons is then divided by this expected pumpage per kwh. the power consumption to be anticipated from the new installation will be secured. Similarly it is possible to determine the anticipated demand rate, which is often as important as is the total kwh. consumption in determining the power bill to be expected from a new installation. Sometimes it is more important.

A Worthy Example

An article by Marshall and Rawlins of Charlotte, N.C., revealed graphically how the power costs were drastically cut at the local pumping station by replacing old equipment with new. These power costs, which had been running about $16.00 per million gallons were cut to about $7.50 per million gallons. This cut was the result of two definite and distinct improvements. In the first place the pumping main was paralleled with a new line. This resulted in reducing the former friction loss materially. This single betterment cut the power cost from $16.00 to $12.00 per million. Following this, the not very old (but less efficient)

pumping units were replaced with modern efficient equipment. This investment, which might appear to the average municipal councilman a questionable expenditure, further reduced the pumping cost to $7.50 per million, representing a very notable day in and day out saving.

Measuring Output of Water

Table 1 has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the same period. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient. Table 1 indicates the discharge woud be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,620,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

HOW TO PACK A STUFFING BOX

1. Remove all old packing from the stuffing box.
2. Clean box thoroughly, removing accumulations from walls.
3. Keep packing clean during application. The scoring of rods, shafts or sleeves often results from grit or foreign matter picked up by packing.
4. Determine size of packing required by checking diameter of rod or shaft and the inside diameter of the stuffing box. Rods wear and the packing has to compensate for this wear.
5. Never wind a length of packing into a stuffing box. Use ring form only.
6. Cut spiral or coil from packing over a shaft or mandrel of exactly the same size as the one on which the packing is to be used in order to get close fitting rings.
7. Obtain sharp clean cuts on soft packings that tend to squash or become ragged by simply applying a small piece of friction tape at the place where the packing is to be cut. It is advisable to remove the tape when installing the rings. String also serves well for tying the packing on each side of where the cut is to be made and may be left on the packing when installed.
8. Cut all packing ring joints to a snug fit making the rings meet with a tight butt or bevel joint.
9. Seat each packing ring carefully before placing the next one in the box. Loading a stuffing box with packing and then pulling up on the gland follower may cause excessive deformation of the first two rings, building up localized gland pressure and failure to seat the bottom rings so they can work effectively.
10. Install all packing rings so that joints are staggered and kept approximately 90 deg. apart. Spot joints in clockwise direction to facilitate locating them when removing packing.
11. Pull up the gland follower sufficiently tight, after the packing has been installed, to insure final seating of the packing. The nuts should be backed off two or three turns to relieve excessive pressure. Adjust packing to operating conditions.
12. Keep the following in mind for stuffing boxes provided with water, oil or grease lanterns: (a) Make sure that the lantern is so located in the box that as the packing is taken up, the lantern will be advanced to its proper location with respect to the opening in the box. (b) Check to see that the opening into the stuffing box is free from obstructions so that the sealing water or lubrication can flow into the lantern.
13. Allow packing to leak a small amount, if possible, when starting a newly packed pump. Take up the gland slowly as the packing seats.
14. Provide means for lubricating the rod and packing wherever possible.
15. Finally, carefully wrap all extra packings, place them back in their container as a precaution against waste and the possibility of their picking up dirt and other injurious foreign substances.

Courtesy of *Power*

HELPFUL HINTS FOR HANDLING PACKINGS

1. Use packings of correct size. Oversize packings are difficult to install and may cause excessive friction. Undersize packings may be ruined by too much takeup.
2. Where leakage cannot be permitted, provide a means of introducing a sealing or lubricating fluid such as water, oil or grease into the stuffing box.
3. When renewing packings, use all new, clean packing. Worn packings are dry, highly compressed, have high friction, may develop scoring.
4. Remember packing is relatively cheap. Labor and materials necessary to replace worn shafts, sleeves or rods are expensive and critical commodities.
5. Take up bolts evenly, moving to the bolt diametrically opposite, never to the bolt adjacent.
6. Follow up bolts the next day after installing new gaskets. For lines carrying high pressures, the gradual building up of the pressure and continuous follow-up of bolts is recommended.
7. Exercise great care when using gasketing dopes. Never use oil or grease on a rubber or rubber-compounded gasket. Graphite and glycerine or molasses compounds are not injurious to rubber. Never use dope on both sides of gasket—it may cause slippage or blowout.
8. Do not use a heavier sheet packing than is necessary. The thinner the gasketing material, the better.
9. Ring gaskets are preferable to full face gaskets where the flanges are heavy enough to prevent distortion.

Courtesy *Johns-Manville Corp.*

NOTES

for the engineer's note book

—ON—

Pumping with Economy

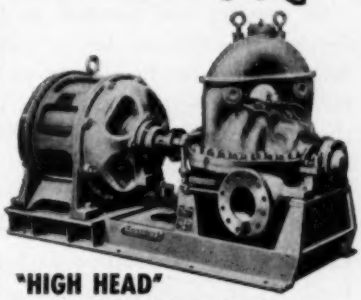
FOR WATER WORKS MEN:

In Village, Town or Metropolis
WHEELER-ECONOMY DOUBLE SUCTION PUMPS are Making Outstanding Records for Dependability and Efficiency

600 HP Installation For City of Denver, Colo.

Single stage, double suction, Split Case Design in sizes from 1½" to 54"

For detailed features, see CATALOG A1052



"HIGH HEAD" IN A COMPACT PUMP

Two Stage Type DMD

Heavy duty, high efficiency with opposed impellers and horizontally split case. Sizes 2" to 10" for capacities to 4,000 GPM and heads to 750 feet. Wheeler-Economy DMD Pumps are used in high head water works applications, buildings, hydraulic elevators, boiler feeding, mines, etc. See CATALOG C351.

FOR SEWAGE MEN:

UNSCREENED SEWAGE HANDLED By Wheeler-Economy Non-Clog Centrifugal Pumps

Wheeler-Economy Horizontal or Vertical Centrifugal Sewage Pumps have clear waterways from 1½" to 10". They pump unscreened sewage, miscellaneous pulp or trash in liquid without difficulty. Where sewage is screened, Mixed Flow types are available for higher speed, more economical operation. Sizes to 36".

Horizontal Type for economical installation, accessibility and to simplify maintenance. CATALOG F447.

For DRY PIT installations:

"Sentry" Type vertical pump with motor direct connected. For dry pit service, not subject to flooding, and to conserve floor space. CATALOG F249.

Open Shaft Type vertical pump with flexible shafting drive from motor. Motor located at distance above pump to avoid possible flooding of electrical equipment and to conserve pump room floor space. CATALOG F249.

For WET PIT installations:

WHEELER-ECONOMY Sump Pumps

Designed in single or duplex units to elevate drainage or sewage from wet pits, sumps, basements, boiler pits, scale and elevator pits, etc. Sizes from 1½" to 3" for drainage free from solids. Sizes 3" to 14", non-clog type for unscreened drainage containing solids. Sump cover and control arrangements can be supplied to meet any requirements. CATALOG E748 for General Service. CATALOG E345 for Non-Clog.

See Your Phone Directory or Write Us for Name of Nearest Distributor for ECONOMY PUMPS, Inc.

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WHEELER-ECONOMY PUMPS

ECONOMY PUMPS, INC. · DIVISION OF C. H. WHEELER MANUFACTURING CO.
19TH AND LEHIGH, PHILADELPHIA 32, PA.

Centrifugal Pump Maintenance and Troubleshooting

1. A Maintenance Timetable

"A" TIMETABLE, not "the" timetable! Operating conditions vary so widely that to recommend one schedule of preventive maintenance for all pumps would be absurd.

So consider this timetable as *relative*. The recommended inspection and service operations may seem too frequent, however, they are based on the severest applications. At any rate, a routine maintenance schedule should be set up and followed to really get the best service out of any pumping equipment.

Every Month

Check bearing temperature with thermometer—not by hand. If anti-friction bearings are running hot, probably they have too much lubricant. Relieve. If sleeve bearings are running too hot, probably they need more lubricant. If change in lubrication doesn't correct condition, dissasemble and inspect bearing. Or possibly the alignment of pump and motor should be checked.

Every 3 Months

Drain lubricant, wash out oil wells and bearings with kerosene. In the case of sleeve bearings, check to see that oil rings are free to turn with the shaft. Repair or replace if defective. Refill with lubricant recommended by your pump manufacturer.

Measure bearings for wear, replace if excessive. Generally, allow 2 thousandths of an inch clearance—plus 1 thousandths of an inch for each inch or fraction of an inch of shaft journal diameter.

Every 6 Months

Replace packing—use grade recommended by pump manufacturer. Be sure seal cages are centered in stuffing boxes at the entrance of water seal piping.

Check shaft sleeves for scoring that would accelerate packing wear—order new sleeves if needed.

Check alignment of pump and motor—shim up units as needed. If misalignment recurs frequently, inspect entire piping system. Unbolt piping at suction and discharge nozzles to see if it springs away—indicating strain on casing. Check all piping supports for soundness and effective support of load.

Every Year

Remove rotating element. Inspect thoroughly for wear—order replacement parts where necessary. Check wearing ring clearances. Generally, they should be approximately no more than .003" per inch on diameter of wearing rings.

Remove any deposit or scaling. Clean out water seal piping.

Measure total suction and discharge lifts as test of pipe conditions. Record figures and compare them with figures of next test.

Inspect foot valves and check valves—especially check valves, which must safeguard against water hammer when pump stops.

2. How to Locate Trouble

No Water Delivered

CAUSES	CURES
1. Lack of prime.	Fill pump and suction pipe *completely* with water.
2. Speed too low.	Check whether motor is directly across-the-line and receiving full voltage. Or frequency may be too low, motor may have an open phase. Correct.
3. Discharge head too high.	Check pipe friction losses. Larger piping may correct condition. Are valves *wide* open?
4. Suction lift too high.	If no obstruction at inlet, check for pipe friction losses. However, *static* lift may be too great. Measure with mercury column or gauge while pump operates. If static lift is too high, water to be pumped must be raised or pump lowered.
5. Impeller completely plugged.	Remove top of pump casing and clean impeller.
6. Wrong direction of rotation.	This sometimes occurs! Compare turning of motor with directional arrow on pump casing.

Parts 1 and 2 are from an Allis Chalmers Mfg. Co. booklet

Not Enough Water Delivered

CAUSES	CURES
7. Air leaks in suction piping.	If liquid pumped is water or other non-explosive—and explosive gas or dust are not present—you can test flanges for leakage with flame or match. For such liquids as gasoline, suction line can be tested by shutting off or plugging inlet—putting line under pressure. Seal leaks.
8. Air leaks in stuffing box.	Check to see if thin stream of water flows from stuffing box while pump operates. If not—and adjusting gland to reasonable extent does not produce flow—new packing probably is needed. Or—water seal piping may be plugged and need cleaning out . . . lantern ring may be displaced and need centering at water seal piping.
9. Speed too low.	See item 2, above.
10. Discharge head too high.	See item 3, above.
11. Suction lift too high.	See item 4, above.
12. Impeller *partially* plugged.	See item 5, above.
13. Defective wearing rings.	Inspect. Replace if worn excessively.
14. Defective impeller.	Inspect. Replace if damaged or blade sections badly eroded.
15. Defective packing.	Replace packing . . . and sleeves, if badly worn.
16. Foot valve too small or partially obstructed.	Inspect. Area through ports of valve should be at least as large as area of suction pipe—preferably 1½ times. If strainer is used, net clear area should be 3 to 4 times area of suction pipe.
17. Suction inlet not immersed deep enough.	If inlet can't be lowered—or if swirling eddies through which air is sucked persist when it is lowered—chain a board to suction pipe. It will be drawn into eddies, smothering the vortex.
18. Wrong direction of rotation.	Symptoms are an overloaded drive and about ⅓ rated capacity from pump. Compare turning of motor with directional arrow on pump casing.

Not Enough Pressure

19. Speed too low.	See item 2, above.
20. Air or gases in liquid—e.g. marsh gas in swamp water. (Test in laboratory, reducing pressure on liquid to pressure in suction line. Watch for bubble formation.)	May be possible to overrate pump to point where it will provide adequate pressure despite condition. Better to provide gas separation chamber on suction line near pump, and periodically exhaust accumulated gas.
21. Mechanical defects.	See items 13, 14, 15, above.
22. Too small impeller diameter (probable cause, if none of (above).	Check with your pump manufacturer to see if a larger impeller can be used. Otherwise, cut pipe losses, or increase speed . . . or both, as needed. ***But be careful that you don't seriously overload your drive.***

Pump Works for a While and Quits

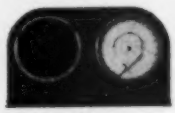
23. Incomplete priming.	Free pump, piping and valves of *all* air. If high points in suction line prevent this, they need correcting.
24. Suction lift too high.	See item 4, above.
25. Air leaks in suction piping.	See item 7, above.
26. Air leaks in stuffing box.	See item 8, above.
27. Air or gases in liquid.	See item 20, above.

Pump Takes too Much Power

28. Head lower than rating, pumps too much water.	Turn down impeller's outside diameter in amount advised by your pump manufacturer.
29. Liquid heavier (in either viscosity or specific gravity) than allowed for.	Use bigger motor.
30. Wrong direction of rotation.	See item 18, above.
31. Stuffing boxes too tight.	Release gland pressure. Tighten reasonably. If sealing water does not flow while pump operates, replace packing. If packing is wearing too quickly, replace scored shaft sleeves and keep water seeping for lubrication.
32. Casing distorted by excessive strains from suction or discharge piping.	Check alignment. Examine pump for friction between impeller and casing, worn wearing rings. Replace damaged parts.
33. Misalignment.	Realign pump and motor.

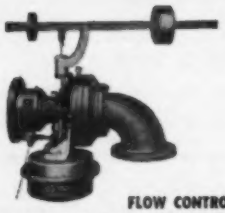
IT'S SIMPLEX– IT'S ACCURATE

Reliable measuring and controlling equipment



FILTER GAUGES indicate and/or record essential data on rate of flow, loss of head and sand expansion. Furnished for operating table or floor stand mounting.

TYPE H METER—Mercury-float type indicating, recording and totalizing unit. Gives ±2% accuracy at any point over flow ranges as wide as 13 to 1. Evenly spaced gradations make accurate readings easy. Available for wall, panel, or floor stand mounting.



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Maintain constant flow regardless of variations in head of filter effluent or wash water. Control within ±3% over 5 to 1 range. Exclusive, balanced guillotine valves quickly respond to slightest pressure differential. Standard sizes from 3″ to 24″.

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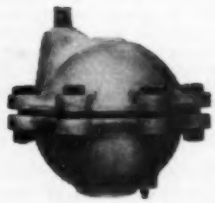

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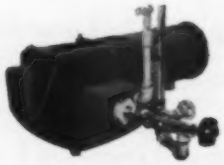

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Selection of Main Line Meters Simplified by Use of Charts

Head losses in Venturi and orifice meters determine their relative economy

By JOHN C. THORESEN
Engineer, Builders-Providence, Inc., Providence, R.I.

EXPERIENCE repeatedly has emphasized the importance of evaluating price in terms of design, specifications and performance to be expected. Most important, the evaluation will consider the non-recoverable loss of head induced by the meter.

Summary

1. Before selecting one differential producer over another for main line metering, an evaluation of the devices should be made on the basis of comparative cost of operation due to power loss caused by friction.

2. A chart (Fig. 5) has been drawn to show the non-recoverable head loss for four differential producers at different ratios of throat to inlet diameter.

3. An Alignment Chart (Fig. 6) has been developed for rapid determination of flow rates, differentials, Venturi Throat and orifice diameters for water at 60°F.

4. By use of Fig. 5 and Fig. 6 and simple calculations the difference in operating cost, due to friction loss, can be determined for the Venturi Tube versus the orifice plate.

5. To simplify these cost difference calculations an Alignment Chart has been developed for power losses in Venturi Tube and other differential producers. This chart and a simplified formula make it possible to determine quickly and easily the comparative cost of operation of differential producers as these costs are caused by friction loss.

6. By following the steps outlined in the "Simplified Procedure" and using the several diagrams, anyone can quickly and easily determine the most economical type of metering device for any installation under consideration.

Friction Loss of Meters

This article will deal solely with the factor of loss of head or friction loss, which causes loss of pressure or power resulting from the insertion of the flow measuring element in the pipe line.

In general, main line meters operate on the inferential principle: that

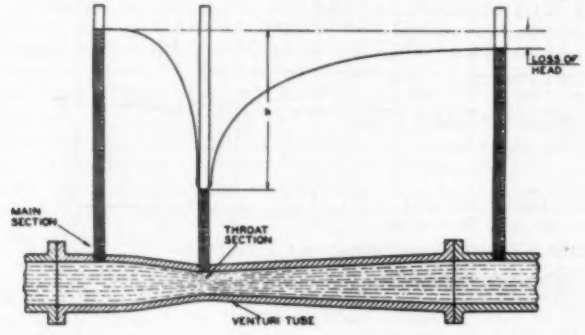

FIG I

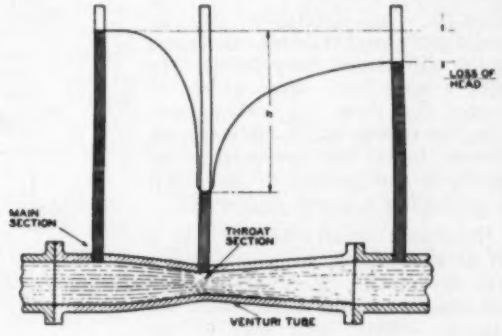

FIG II

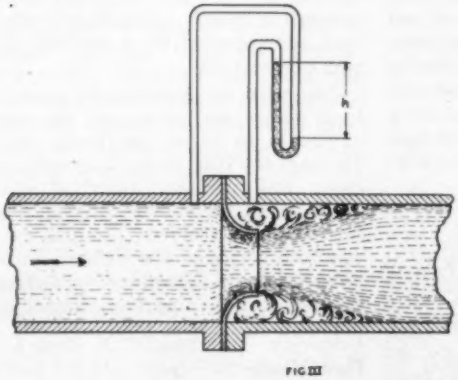

FIG III

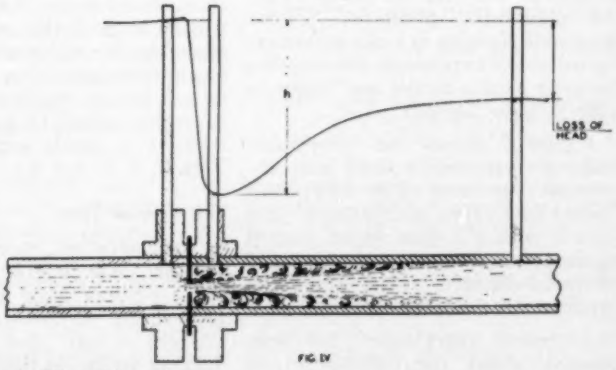

FIG IV

FOUR FORMS of differential producers

Fig. 1—Venturi tube
Fig. 2—Venturi tube, short form
Fig. 3—Flow nozzle
Fig. 4—Flat plate orifice

is, the rate of flow is "inferred" from a difference in pressure between two points by a "restriction" placed in the pipe line, with the pressure difference transmitted to the recording instrument through which no flow occurs.

All water works men know that elbows, tees, partly closed valves, and other fittings add to pipe line friction loss and must be reckoned with in the design of the system. Meters, too, cause friction loss. Friction is important because—whether water is lifted first to a reservoir or pumped directly through the pipe line—the additional load due to friction is reflected back upon the pumps, requiring provisions for more horsepower than otherwise would be required, and power always costs money.

Differential Producers

There are only a few forms of "differential producers" for insertion in pipe lines. Figures 1, 2, 3, and 4 show the four types most widely used: Herschel Standard Venturi Tube, Short-form Venturi Tube, Flow Nozzle and Orifice. The primary purpose of each of these devices is to produce a differential pressure. This differential may be read directly and the flow calculated, or the differential may be used to drive a secondary meter which indicates the flow. In either case, from the standpoint of *efficiency* the correct basis for comparison of meters is the amount of head lost in producing a given differential.

Head loss usually is given as a percentage of the differential pressure developed. (Recoverable head loss equals 100 per cent minus the non-recoverable head loss in per cent.) For liquids of certain characteristics (large Reynolds Numbers) this percentage has been found to depend only on the geometry of the differential producer. (Note: Reynolds Number is a dimensionless figure which represents the relation between inertia forces and viscosity forces in the liquid.)

Figure 5 shows the recoverable and non-recoverable head loss, expressed as per cent of the differential for the four types of differential producers with the data being plotted against the B ratio (i.e., the ratio of throat diameter of the differential producer to the inlet diameter).

In recent years much has been learned about the mechanism of friction losses in flowing fluids. Without dealing with terms such as pressure gradient, boundary layer,

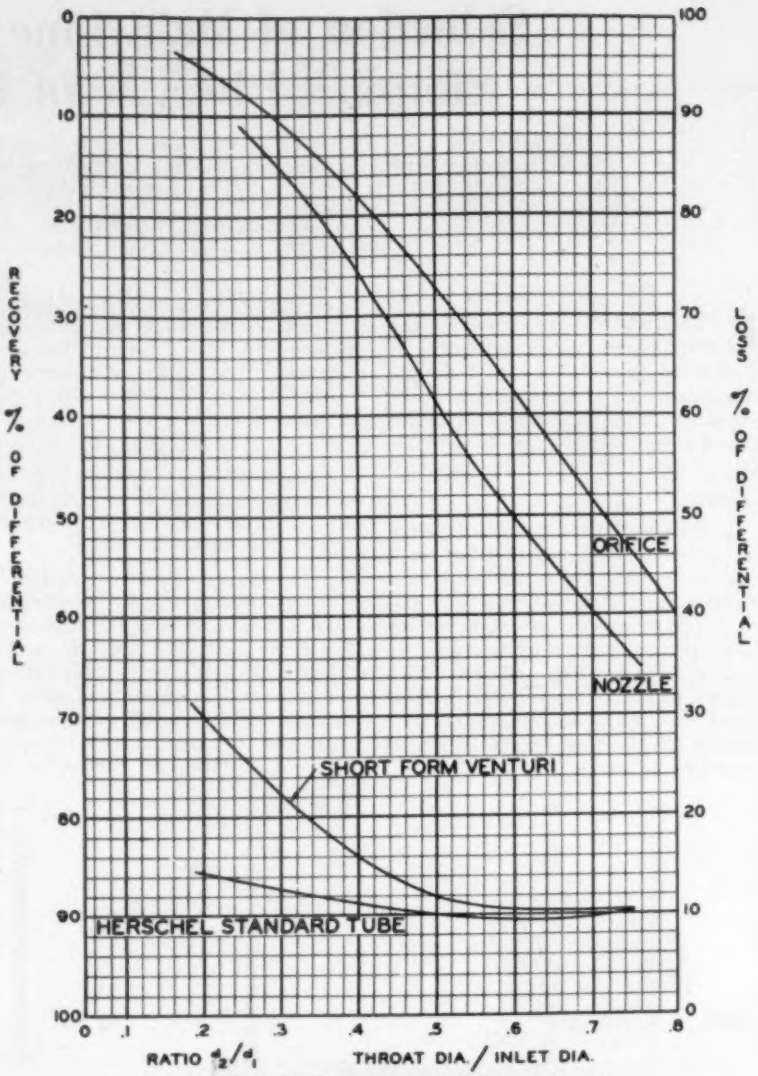

Fig. 5—RECOVERY CHARACTERISTICS of differential producers

and separation, it may be stated that the principal losses occur almost entirely in the expansion which takes place following the necessary constriction in the meter. This loss will be large if the expansion takes place rapidly and is accompanied by much turbulence, but the loss will be minimized by providing slowly diverging walls to guide the flow through a gentle expansion. (See Figs. 1, 2, 3, and 4.)

The Venturi Tube

The Herschel Standard form of Venturi Tube (Fig. 1), and the short form Venturi Tube (Fig. 2), both incorporate a "streamlined" inlet, straight throat, and gradually diverging walls. As liquid moves from the inlet through the tube there is a rapid increase of velocity with a decrease in pressure until the throat is reached. At that point the speed of flow may be ten or more times that at the inlet. After passing the throat the velocity is decelerated through a gently expanding outlet cone, accompanied by a gradual regain of pressure.

The velocity distribution is uniform across the throat and the rate of flow is based on the throat area. Throughout this interchange of velocity and pressure there is wall guidance of the flowing stream and turbulence is avoided. For this reason both forms of the Venturi Tube have a definite advantage over other devices in the important matter of pressure loss. (See Fig. 5.)

Flow Nozzle

Figure 3 illustrates one form of flow nozzle with a well rounded approach. It is apparent (Fig. 3) that

once the fluid leaves the minimum diameter it is free to form its own expanding boundaries. This expansion is accompanied by severe turbulence in the surrounding annular space, thereby occasioning a relatively high overall pressure loss. (See Fig 5.)

Orifice Plate

The orifice plate (Fig. 4) is essentially a flat plate with a carefully machined hole in the center inserted between the flanges of the main pipe. As flowing water approaches the orifice plate, the lines of flow undergo an abrupt change in direction (nearly 90 degrees) and after passing through the orifice opening, start to expand until the pipe line is completely filled. Turbulence occurs in the annular space around the orifice and causes a relatively high overall pressure or head loss.

Relative Head Loss

Figure 5 shows a comparison of friction loss for the four types of differential producers. These losses are plotted as per cent of differential pressure against the B ratio: throat diameter divided by inlet diameter (d_2/d_1).

The steep slope of the two upper curves for the Orifice and Flow Nozzle are in sharp contrast to the Venturi curves. In the Venturi Tube the friction loss changes but a few per cent over a wide range of throat diameter to inlet diameter ratios (d_2/d_1). On the contrary the friction loss changes greatly for the nozzle and orifice over the same range of B ratios.

Furthermore, the recoverable head loss is greater for all B ratios in the Venturi Tube than in either the Flow Nozzle or Orifice. In order to obtain a value of recoverable head loss in the Orifice or Nozzle somewhat comparable to that in the Venturi Tube, a nozzle or orifice of larger opening than the Venturi Tube may be used, but increasing the size of the orifice or nozzle opening also reduces the differential pressure obtainable at any given rate of flow and thus results in a lower measuring range. This may readily be determined by calculation or by use of an alignment chart.

Alignment Chart for Rate of Flow

Figure 6 shows an alignment chart for the rapid determination of flow rates, differentials, Venturi Tube throat and orifice diameters. Directions for using this chart are shown on the chart, and results obtained from the chart may be used to compare different types of differential producers as to size and measuring range.

Venturi Tube vs. Orifice Measuring Range

In order to show that an orifice of comparable head loss to a Venturi Tube is larger and has a lower measuring range we may cite the following comparison as an example: A 10-in. Herschel Standard Venturi Tube with a 4-in. throat; rate of flow=1400 gpm; B ratio (d_2/d_1)= 0.4. From example 3 in Fig. 6 in appears that the differential head produced is 240 in. of water.

From Fig. 5 the non-recoverable loss of head for a B ratio of 0.4 is seen to be 11.5 per cent. Therefore, the head loss for this particular Venturi Tube is 0.115 × 240, or 27.6 in. of water. For purposes of practical calculation it may be assumed that the average meter recording instrument will not record changes of less than 0.01 in. If this change represents a performance accuracy of 1 per cent of the differential pressure, then the minimum differential pressure which can be recorded is 1.0 in.

Since the rate of flow varies as the square root of the differential pressure produced, the accurate measuring range of the Venturi Tube is $\sqrt{240}/1$ or 15.5 to 1. This means that the Venturi Tube will accurately measure flows over a range from 1400 to 90 gpm.

By trial and error, it may be determined that an orifice plate having the same non-recoverable loss of head (27.6 in.) would have an opening of approximately 6.97 in., or a B ratio (d_2/d_1) of 0.697. For this size orifice, a flow of 1400 gpm would have a differential of 53 in. as determined from Fig. 6. From Fig. 5, it is determined that the non-recoverable head loss for a B ratio of 0.697 is 52 per cent. Multiplying this percentage by the differential (53 in.) it is possible to show the non-recoverable head loss for the orifice to be 27.6 in. and thus to check the trial and error calculation.

Since the minimum effective differential is 1.0 in., therefore the accurate measuring range of the orifice plate is equal to $\sqrt{53}/1$ or 7.3 to 1; i.e., about half that of the Venturi Tube. It will be obvious from Fig. 5 that a flow nozzle would be somewhat better than an orifice and a short form Venturi Tube only slightly poorer than the Herschel Standard Venturi Tube.

Practical Problems

Having shown briefly the relative characteristics of the two principal differential producers, we may now determine the practical significance of these characteristics as they appear in common problems met in water works practice.

Horsepower is measured in foot-pounds of work performed in a definite time period. If we raise a 50 pound weight to a height of one foot, the work done is 50 foot-pounds. By analogy, if we have 8,340 pounds of water (1000 gal) per minute flowing through a pipe line and if the head loss due to friction is one foot, the result is the same as though the water had been raised one foot, or work is being done (energy expended) at the rate of 8,340 foot-pounds per minute.

Work done or energy expended means power used, and power has a dollar value. Two practical problems may be cited to illustrate the method of determining the comparative cost of using Venturi Tubes versus orifice plates.

Problem A

FACTORS: Water pumped at 3700 gpm through a 16 in. line. Electrically driven pump with overall (wire to water) efficiency of 70 per cent. Average operating period 15 hours per day for 360 days a year (5400 hours). Power cost 2c per kwh.

VENTURI TUBE: A 16-in. Herschel Standard Tube with 6½-in. throat. B ratio (d_2/d_1)=6.5/16.0=0.405. Using the Alignment Chart (Fig. 6), it may be determined that the differential for this Venturi Tube will be 240 in. of water or 20 ft. From Fig. 5 the friction loss is determined to be 11.5 per cent; in this case equal to 2.3 ft. (0.115 × 20).

CALCULATION: The cost of power loss due to friction is as follows:

3700 gpm x 8.34 = 30,858 lb. per min
Energy loss = 30,858 x 2.3 = 70,973 ft-lb. per min
Horsepower loss = 70,973/33,000 = 215 hp
Equivalent electrical power loss = 2.15 x 0.746 = 1.605 kw
Corrected electrical power loss (for motor and pump efficiency) = 1.605/0.70 = 2.29 kw
Cost of power loss per year = hr. of operation x kw loss x cost per kwh = (360 x 15) x 2.29 x 0.02 = $247.00

ORIFICE PLATE: From Fig. 6 it is determined that an orifice plate for the same differential at the maximum flow (3700 gpm) would have an opening of 8.25 in. B ratio (d_2/d_1)=8.25÷16=0.515. From Fig. 5 the friction loss for this B ratio is found to be 71 per cent or for this orifice 0.71 x 20 ft.=14.2 ft.

CALCULATION: The cost of power loss due to friction is as follows:

Energy loss = 30,858 x 14.2 = 438,183 ft-lb per min
Horsepower loss = 438,183/33,000 = 13.28 hp

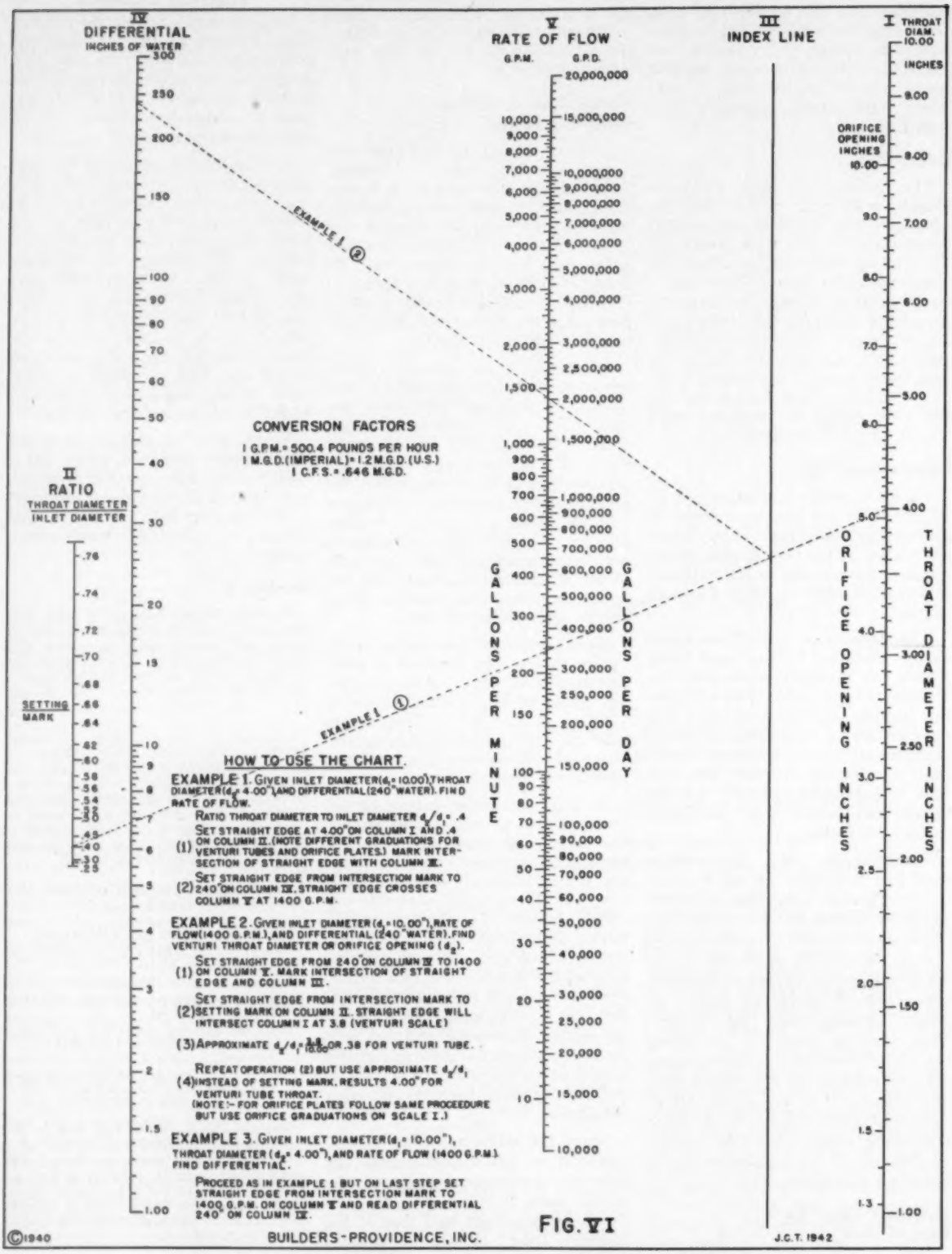
IV
DIFFERENTIAL
INCHES OF WATER
V
RATE OF FLOW
G.P.M.
G.P.D.
III
INDEX LINE
I THROAT DIAM.
INCHES
ORIFICE OPENING INCHES
II
RATIO
THROAT DIAMETER / INLET DIAMETER
SETTING MARK
GALLONS PER MINUTE
GALLONS PER DAY
ORIFICE OPENING INCHES
THROAT DIAMETER INCHES
EXAMPLE 1
CONVERSION FACTORS
1 G.P.M. = 500.4 POUNDS PER HOUR
1 M.G.D.(IMPERIAL) = 1.2 M.G.D.(U.S.)
1 C.F.S. = .646 M.G.D.
HOW TO USE THE CHART.
EXAMPLE 1. GIVEN INLET DIAMETER(d_1 = 10.00"), THROAT DIAMETER(d_2 = 4.00") AND DIFFERENTIAL (240" WATER). FIND RATE OF FLOW.
RATIO THROAT DIAMETER TO INLET DIAMETER d_2/d_1 = .4
(1) SET STRAIGHT EDGE AT 4.00" ON COLUMN I AND .4 ON COLUMN II. (NOTE DIFFERENT GRADUATIONS FOR VENTURI TUBES AND ORIFICE PLATES.) MARK INTERSECTION OF STRAIGHT EDGE WITH COLUMN III.
(2) SET STRAIGHT EDGE FROM INTERSECTION MARK TO 240" ON COLUMN IV. STRAIGHT EDGE CROSSES COLUMN V AT 1400 G.P.M.
EXAMPLE 2. GIVEN INLET DIAMETER(d_1 = 10.00"), RATE OF FLOW (1400 G.P.M.), AND DIFFERENTIAL (240" WATER). FIND VENTURI THROAT DIAMETER OR ORIFICE OPENING (d_2).
(1) SET STRAIGHT EDGE FROM 240" ON COLUMN IV TO 1400 ON COLUMN V. MARK INTERSECTION OF STRAIGHT EDGE AND COLUMN III.
(2) SET STRAIGHT EDGE FROM INTERSECTION MARK TO SETTING MARK ON COLUMN II. STRAIGHT EDGE WILL INTERSECT COLUMN I AT 3.8 (VENTURI SCALE)
(3) APPROXIMATE $d_2/d_1 = \frac{3.8}{10.00}$ OR .38 FOR VENTURI TUBE.
(4) REPEAT OPERATION (2) BUT USE APPROXIMATE d_2/d_1 INSTEAD OF SETTING MARK. RESULTS 4.00" FOR VENTURI TUBE THROAT.
(NOTE:- FOR ORIFICE PLATES FOLLOW SAME PROCEEDURE BUT USE ORIFICE GRADUATIONS ON SCALE I.)
EXAMPLE 3. GIVEN INLET DIAMETER(d_1 = 10.00"), THROAT DIAMETER(d_2 = 4.00"), AND RATE OF FLOW (1400 G.P.M.). FIND DIFFERENTIAL.
PROCEED AS IN EXAMPLE 1 BUT ON LAST STEP SET STRAIGHT EDGE FROM INTERSECTION MARK TO 1400 G.P.M. ON COLUMN V AND READ DIFFERENTIAL 240" ON COLUMN IV.
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FIG. VI
J.C.T. 1942

Fig. 6—ALIGNMENT CHART for rapid determination of flow rates, differentials, venturi throat and orifice diameters for water at 60°F

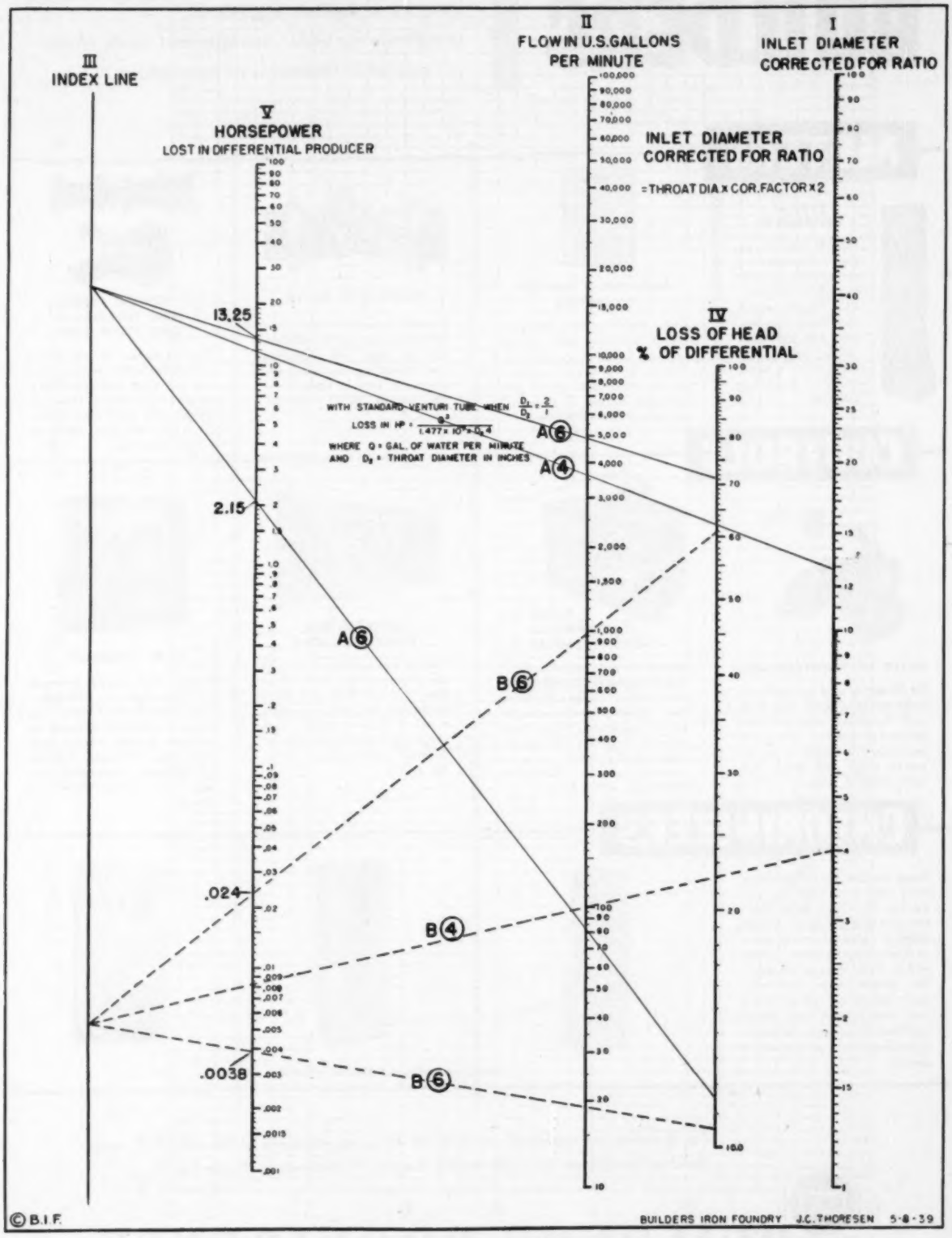

Fig. 7—ALIGNMENT CHART for power losses in venturi and other differential producers

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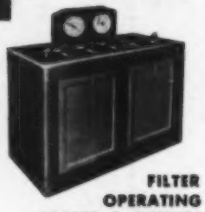

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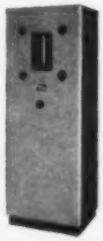

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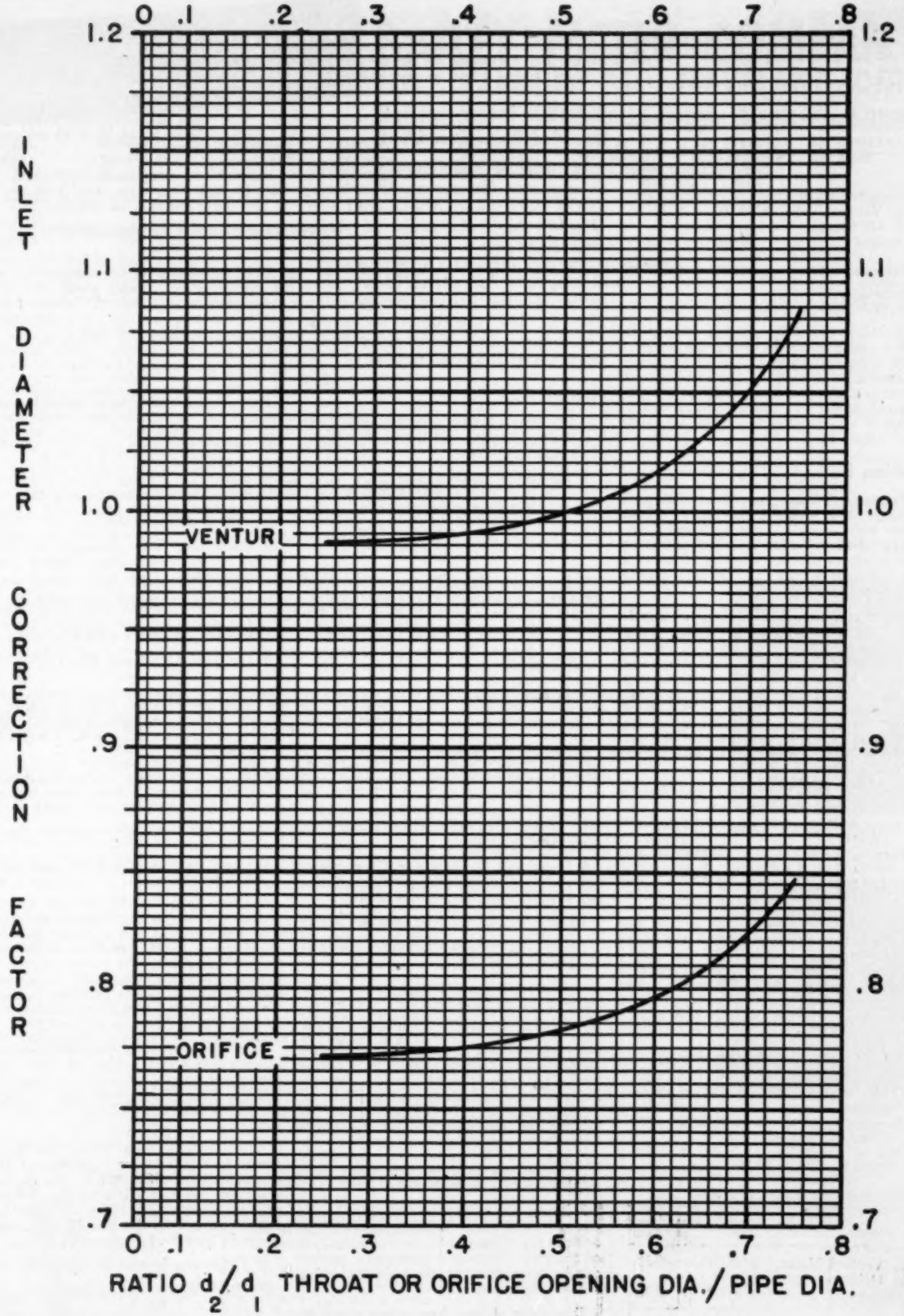


Fig. 8—CORRECTION FACTOR CURVES for use with alignment chart for power losses

Electrical power loss = 13.28 x 0.746 = 9.91 kw
Corrected electrical power loss (for motor and pump efficiency) = 9.9/0.7 = 14.16 kw
Cost of power loss per year — (360 x 15) x 14.16 x 0.02 = $1529

EVALUATION: Respective costs are as follows:

	Original Cost	Annual Power Loss Cost
16-in. Venturi Tube	$1760.00	$ 247.00
16-in. Orifice & Flanges	299.00	1529.00
Difference	$1461.00[1]	$1282.00[2]

(1) In favor of Orifice
(2) In favor of Venturi

Omitting depreciation, the saving in power consumption by using the Venturi Tube is equivalent to 87.7 per cent on the difference in investment. The savings on power consumption alone will pay for the Venturi Meter in less than two years, which is an obvious reason for selecting the Venturi Meter.

Problem B

FACTORS: Water pumped at 100 gpm through 4-in. line. Electrically driven pump with overall (wire to water) efficiency of 60 per cent. Average operating time of motor driven pump for 15 hours a day, 350 days a year (5,250 hours). Power cost 2 cents per kwh.

VENTURI TUBE: A 4-in. Herschel Standard Tube with 2-in. throat designed for a maximum rate of 350 gpm. B ratio = $d_2/d_1 = 2.00/4.00 = 0.5$. Using the Alignment Chart in Fig. 6 it may be determined that the differential pressure across the Venturi connections at 100 gpm is 18.75 in. of water. From Fig. 5, the friction loss for a B ratio of 0.5 is found to be 10.0 per cent; in this case equal to 1.87 in. or 0.156 ft. (0.10 x 18.75).

CALCULATION: The power loss due to friction is done as in Problem A:

hp loss = (100 x 8.34 x 0.156)/33,000 = 0.003942
Electrical power loss = (0.003942 x 0.746)/0.60 = 0.0049 kw
Cost of power loss per year = 5250 x 0.0049 x 0.02 = $0.51

ORIFICE PLATE: From Fig. 6 it is determined that an orifice with the same differential pressure of 18.75 in. would have a plate opening of 2.49 in. B ratio $(d_2/d_1) = 2.49/4.00 = 0.622$. From Fig. 5, the friction loss for this B ratio is determined to be 60.5 per cent, or for this orifice 0.605 x 18.75 = 11.34 in. or 0.945 ft.

CALCULATION: Power loss due to friction is calculated as above:

hp loss = (100 x 8.34 x 0.945)/33,000 = 0.02385
Electrical power loss = (0.02385 x 0.746)/60 = 0.02965 kw
Cost of power loss per year = 5250 x 0.02965 x 0.02 = $3.11

EVALUATION: Respective costs are:

	Original Cost	Annual Power Lost Cost
4-in. Venturi Meter	$445.00	0.51
4-in. Orifice & Flanges	87.00	3.11
Difference	$358.00[1]	2.60[2]

(1) In favor of Orifice
(2) In favor of Venturi

In this case, at a difference of power loss cost of only $2.60 per year, it would require almost 140 years for this saving to pay the difference in the cost of the Venturi Tube. From a monetary point of view, therefore, the orifice should be selected.

Simplified Power Loss Chart

In order to simplify the calculations needed for any meter installation, a Horsepower Alignment Chart (Fig. 7) has been prepared. It is easy to use and is accurate to within a few per cent. To accompany the Horsepower Alignment Chart, Correction Factor Curves are given in Fig. 8. The procedures by which Fig. 7 and 8 are used to solve Problems A and B are as follows:

Problem A

For a flow of 3700 gpm compare Venturi Tube (16 x 6½ in.) with orifice plate (16 x 8.25 in.):

1. Calculate B ratios:
   Venturi Tube = 6.5/16 = 0.406
   Orifice Plate = 8.25/16 = 0.515
2. From Fig. 8 find correction factor:
   Venturi Tube = 0.992
   Orifice Plate = 0.783
3. Determine "Inlet Diameter Corrected for Ratio." Multiply either the Venturi Throat or the orifice opening by the "Correction Factor" and a factor of two.

   Venturi Tube = 6.5 x 0.992 x 2 = 12.896
   Orifice Plate = 8.25 x 0.783 x 2 = 12.919

(Theoretically these two values should be the same and their close agreement is evidence of the accuracy of the charts.)

4. On the Alignment Chart (Fig. 7) place a straight-edge on point 12.9 on Scale I (Corrected Inlet Diameter) and on point 3700 gpm on Scale II (Rate of Flow). Determine point where straight-edge crosses the *Index Line* (Scale III). Line A ④ on Fig. 7.
5. From Fig. 5 (Recovery Characteristics Chart) determine the friction loss for the Venturi Tube and orifice plate.

   Venturi = $d_2/d_1 = 0.406$; head loss = 11.5 per cent
   Orifice = $d_2/d_1 = 0.515$; head loss = 71.0 per cent

6. Place the straight-edge on the determined point on the Index Line (Scale III) and on point 11.5 per cent on Scale IV (Loss of Head, Per cent of Differential) and determine the point at which the straight-edge crosses Scale V (Horsepower); in this case 2.15 for the Venturi Tube (Lower Line A ④ on Fig. 7).

   Repeat this step for the orifice plate by placing the straight-edge on the Index Line Point and on point 71 on Scale IV and read the Horsepower Loss on Scale V; in this case 13.25 for the orifice plate (Upper Line A ⑥ on Fig. 7).
7. From these two values for horsepower loss (2.15 for Venturi and 13.25 for orifice) the difference in cost of operation of the two differential producers quickly can be determined by using the following simplified formula:

   Excess cost of operation: orifice over Venturi Tube =

$$\frac{hp_o - hp_v \times K \times T \times C}{E}$$

where
hp_o = horsepower loss for orifice plate
hp_v = horsepower loss for Venturi Tube
K = Conversion factor, hp to kwh = 0.746
T = Total hours of operation
C = Cost of power per kwh
E = Wire to water efficiency of pumping unit (motor and pump) usually in the 50 to 80 per cent range

8. Substitute the values obtained in Step ⑥ and other data from Problem A in the above formula as follows:

$$\frac{(13.25 - 2.15) \times .746 \times (360 \times 15) \times \$0.02}{0.70} = \$1283$$

This value ($1283) for the excess cost of operating the orifice plate over and above that of the Venturi Tube is practically the same as the value calculated in Problem A above ($1282).

Problem B

For a flow of 100 gpm compare Venturi Tube (4 x 2 in.) with orifice (4 x 2.49 in.):

1. Calculate B ratios:
   Venturi Tube = 2/4 = 0.5
   Orifice Plate = 2.49/4.0 = 0.622
2. From Fig. 8, find correction factor
   Venturi Tube = 1.0
   Orifice Plate = 0.8
3. Determine "Inlet Diameter for Corrected Ratio," either from Venturi Tube or orifice plate.

   Venturi Tube = 2.00 x 1.00 x 2.0 = 4.0
   or
   Orifice Plate = 2.49 x 0.8 x 2.0 = 4.0

4. On the Alignment Chart (Fig. 7) place a straight-edge on point 4.0 on Scale I (Corrected Inlet Diameter) and on point 100 gpm on Scale II (Rate of Flow). Determine point where straight-edge crosses Scale III (Index Line) Line B ④ on Fig. 7.
5. From Fig. 5 (Recovery Characteristics Chart) determine the friction loss for the Venturi Tube and orifice plate.

   Venturi Tube = $d_2/d_1 = 0.5$; head loss = 10.0 per cent
   Orifice Plate = $d_2/d_1 = 0.622$; head loss = 60.5 per cent

6. Place the straight-edge on the determined point on the Index Line (Scale III) and on point 10.0 per cent on Scale IV (Loss of Head, Per Cent of Differential) and determine the point at which the straight-edge crosses Scale V (Horsepower); which in this problem is 0.0038 for the Venturi Tube (Lower Line B ⑥ on Fig. 7).

   Repeat this step for the orifice plate by placing the straight-edge on the Index Line point and on point 60.5 on Scale IV, and read the Horsepower Loss on Scale V; in this case, 0.024 (Upper Line B ⑥ on Fig. 7).
7. From these two values for horsepower loss (0.0038 for Venturi and 0.024 for orifice) the difference in cost of operation of the two differential producers can be determined by substituting the proper values in the simplified formula given in Step 7 of Problem A, above.
8. Difference in cost of operation =

$$\frac{(0.024 - 0.0038) \times 0.746 \times 5250 \times 0.02}{0.6} = \$2.63$$

This value ($2.63) agrees closely with the value as calculated ($2.57) in the above Problem B solution.

METERS : GAGES : CONTROLLERS
for Sewage Treatment and Water Supply

BAILEY METER COMPANY

1072 IVANHOE RD., CLEVELAND, OHIO
Bailey Meter Company Limited, Montreal, Canada

Atlanta, Boston, Buffalo, Charlotte, Chicago, Cincinnati, Cleveland, Denver, Detroit, Houston, Kansas City, Los Angeles, Milwaukee, New Orleans, New York, Philadelphia, Pittsburgh, San Francisco, Schenectady, Seattle, St. Louis, St. Paul

STANDARD BAILEY REGISTERS

Standard Bailey Registers measure flow of sewage, industrial wastes, sludge, dirty water, or other liquids in open channels or in pipe lines. They also measure air flow, pH, liquid level in open and closed tanks and reservoirs, and other factors.

• • • **FOR OPEN CHANNELS—The Bailey Flume or Weir Meter** is simple and accurate. As shown in the illustration (right), it consists of a single float connected by a flexible cable to a sturdy indicating, recording and integrating mechanism which may be mounted on a panel board, a wall, or a column. It is adaptable to all open channel metering devices including flumes, weirs and nozzles and can be adjusted to any required operating range. Remote location is possible through use of a Bailey Telemeter, (see below). **Ask for Bulletin 62**

• • • **FOR PIPE LINES—The Bailey Open Float Type Meter** measures flow of sewage, sludge, dirty water, or other liquids in pipe lines using Venturi Tubes, flow nozzles, or eccentric orifices. It operates through a differential gearing and cam mechanism from floats which rest on the liquid surfaces in float tubes.

The Bailey Fluid Meter accurately measures flow of steam, liquids, and gases in pipe lines at high or low pressures. A Venturi Tube, flow nozzle, or orifice, is used as the differential producing device and the meter indicates, records and integrates on a Standard Bailey Register. This meter may also provide records of pressure, temperature or liquid level on the same chart. **Ask for Bulletin 301 B**

• • • **FOR LIQUID LEVEL**—Bailey Registers may be used in measuring liquid level in open tanks and reservoirs. Three methods are available to meet any requirement.

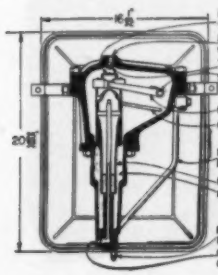
Open Float Method—(for location above liquid level). Has a minimum range of 0 to 5 inches of water and a maximum range of 0 to 60 feet of water.

Static Pressure Method—(for location below liquid level). Two types are available; mercury U-tube and float for minimum range of 0 to 50 inches of water, and maximum of 0 to 150 feet of water, and a helical coil for minimum range of 0 to 120 feet of water and maximum of 0 to 600 feet of water.

Bubbler System—For measuring level or specific gravity of corrosive liquids and of liquids with solids in suspension. **For information on Bailey Level Recorders ask for Bulletin 17-C**

• • • **FOR AIR FLOW—Bailey Air Meters** measure Air Flow in main lines and in individual lines to aeration tanks. The register used is similar in appearance to the Ledoux bell type (left) and the flow mechanism is designed to operate on a maximum differential pressure of eight inches of water. **Ask for Bulletin 301 B**

Air Flow from a rotary positive type blower can be measured accurately with a Bailey Electronic Type Recorder. Blower Shaft speed, measured by a tachometer is recorded in terms of Air Flow.

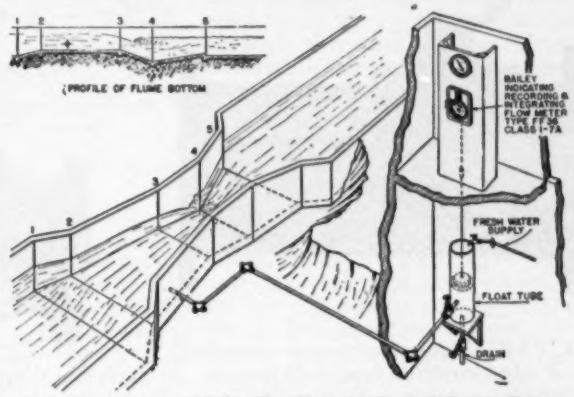


Ledoux Bell Flow Mechanism

BAILEY CONTROLLERS

Bailey Controllers utilize standard Bailey Instruments as the measurement source for automatic control of factors such as flow, ratio, pressure and liquid level. They operate by compressed air and are styled to match other Bailey Gages and Registers.

Bailey Control is fully automatic, dependable and exceptionally flexible. **Explained in Bulletin 17-C**


PROFILE OF FLUME BOTTOM
BAILEY INDICATING RECORDING & INTEGRATING FLOW METER TYPE FF 35 CLASS 1-7A
FRESH WATER SUPPLY
FLOAT TUBE
DRAIN

Typical installation of Bailey Flow Meter for Parshall Venturi Flume

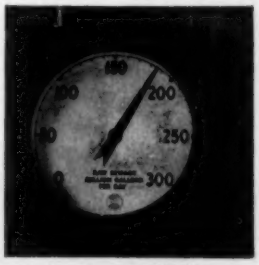
pH RECORDER

The Bailey Electronic pH Recorder accurately measures and, if desired, controls hydrogen ion concentration in a solution. The indicating and recording instrument is similar in appearance to a Standard Bailey Register. **Described in Bulletin 234**

Bailey Recorder—Controller

BAILEY TELEMETER

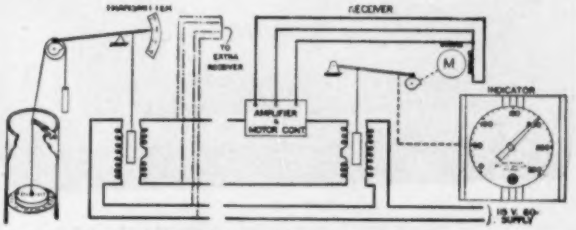
The Bailey Voltage Balance Electronic Telemeter is a quick, accurate means of transmitting position over distances. The measure of any factor which can be made to move the core of a small solenoid transformer may be indicated or recorded at a distant receiver. Multiple receivers may be connected to one transmitter. Several flow measurements can be totalized.



Bailey Large Dial Indicator

LARGE DIAL INDICATOR

Indicators containing the telemeter circuit receiving mechanism may be single or double face and may have 18, 24, or 30-inch dials. Numerals and indicating pointer are large for easy reading. **Ask for Bulletin 17-C**

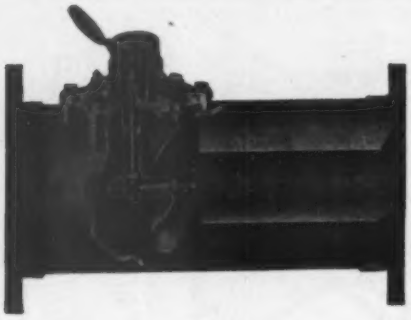


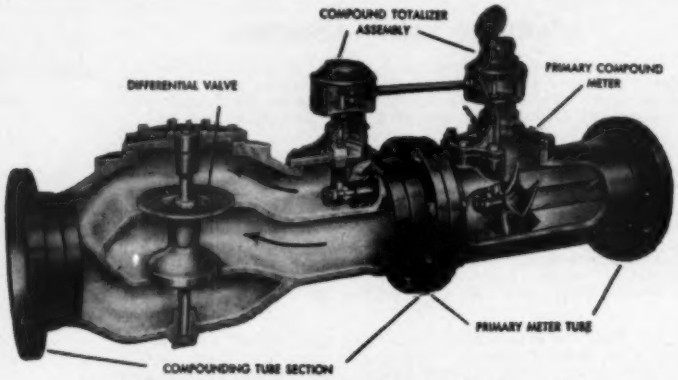
Bailey Voltage Balance Electronic Telemeter Circuit

SPARLING METER COMPANY
INCORPORATED

LOS ANGELES 54.....Box 3277
CHICAGO 8.....1500 South Western Ave.
BOSTON 8.....6 Beacon St.
DALLAS 1....726 Reserve Loan Life Bldg.
KANSAS CITY 6, MO.....6 East 11th St.

626 Broadway.....CINCINNATI 2
101 Park Avenue.....NEW YORK 17
1932 First Avenue.....SEATTLE 1
66 Luckie Street N.W.....ATLANTA 3
85 Industrial St.....SAN FRANCISCO 24





COMPOUND Meters for Mains 6-inch to 36-inch

Consistent accuracy over flow-range as wide as 1-to-125

Differential valve cracks at about one pound per square inch back pressure from the smaller meter. The smaller meter measures all flows below the minimum accurate range of the larger meter. Both meters drive through ratchet clutches to a common totalizer, which thus operates with the faster turning meter.

SPARLING is the name to remember when metering your main lines. Installed as easily as a length of the pipe itself, the Sparling Meter gives you Direct Action Totalization actuated by the flow in the pipe without further instrumentation.

Negligible loss of head pressure is characteristic of Sparling Meter performance. Little maintenance is required to assure continuing Satisfaction, as is proven by 35 years of Service from Coast to Coast!

SPARLING Meters can be mounted on the suction or the discharge side of pump, horizontally, vertically, or on an angle.

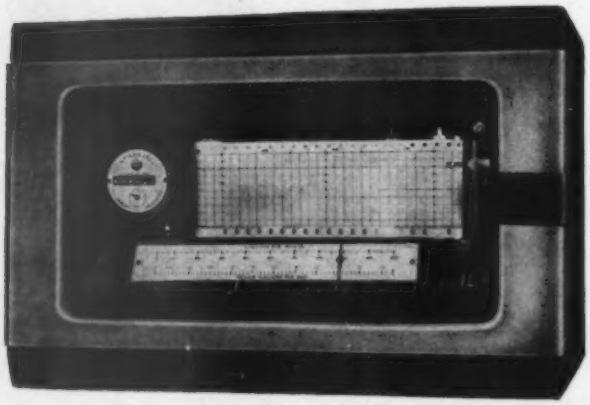
Every Sparling Meter is triple-tested, throughout its rated range, for accuracy within 2 per cent.

FLANGED TUBES—2-inch to 36-inch
SCREW TUBES—2-inch to 6-inch
BELL & SPIGOT—4-inch to 36-inch
SADDLE-MOUNTED—6-inch to 72-inch

INDICATORS • RECORDERS
TOTALIZERS • CONTROLS

Flow-rate indicators and recorders are available for use with Sparling Meters if, as and when required. The mercury-governor type, with circular charts for 24-hour or 7-day records, are mechanically controlled within 15 feet of the meter, or electrically controllel at any distance.

Type 225, shown at right, electric remote control actuated by differential mechanism to indicate and record 1 to 33 range of flows.



Choice of Pedestal, Wall or Panel mounted.

The Striptograph, shown at left, has a straight-reading 60-day strip roll chart. Indicator scale is calibrated in two flow equivalents. The mechanism swings out for easy servicing.

In many Sparling Instrument cases, the mechanism can be swung out, as shown above, for easy inspection and servicing. This feature is especially appreciated where the working space available is quite limited.

Mechanical or electric controls for auto-metered chemical feed are available.

Bulletin 313 comes upon request

Main Line Metering With Propeller Meters

by JAMES M. MONTGOMERY
Consulting Engineer, Pasadena, Calif.

THE principle of the current meter has been used as a primary metering element for the measurement of stream flows for many years. Since 1924 this same current meter principle has been applied as a primary element for the measurement of main line flows by the Sparling Meter Co., Los Angeles, California, and since 1944 by Builders-Providence, Inc., of Providence, R.I. This type of meter has proven itself well suited for this purpose.

Characteristics

The current metering principle is well adapted for main line measurement as the action of the propeller is solely dependent upon the velocity of the flow in the line. The pressure requirement is only that which will always maintain a full pipe of water. The loss of pressure caused by the metering element in sizes 6-in. and larger does not exceed 6 inches of water at normal maximum pipe velocity.

Continued accuracy of the current type meter is dependent chiefly upon maintaining a clean metering section, keeping the propeller free from incrustation and preventing solids, which might damage the propeller, from entering the pipe line. The plastic propeller has proven itself well suited for this purpose, as it is practically inert and will resist both corrosion and electrolytic action. In order to maintain a uniform meter section the propeller assembly may be mounted either in a cast iron, steel,

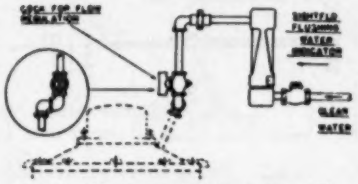


Fig. 1—Continuous flushing system with Builders Sightflo indicator

or bronze tube with a liner and straightening vanes.

Meter Features

Propeller type meters as manufactured by the Sparling Meter Co., and by Builders-Providence, Inc., have high accuracy over wide range, measuring within plus or minus 2 per cent of actual flow from about 10 per cent to 100 per cent rated capacity. Both manufacturers' meters have an "open upper limit" or temporary overload range, where the meters will continue to register with good accuracy at rates up to at least 150 per cent of rated capacity. Both the Sparling and the Builders meters are self-contained and self-operated, requiring no mercury, pressure piping or electrical connections; they are as easy to install as a valve or fitting with no adjustments required in the field.

One feature of the Builders Propeloflo Meter is the Venturi design. This produces an increased and consequently more stable velocity at the point where the fluid acts on the propeller. This increased velocity also produces added power, which is of value when applying secondary units to the meter.

Both types of meters can be used with secondary instruments, either cable-driven or electrically-operated totalizers only, totalizer-recorders or totalizer-indicator-recorders for nearby or remote location, when so specified. They may also be used in conjunction with electric alarm registers, where measurement of a pre-determined quantity of liquid is required.

With the Builders, Propeloflo Meter a continuous flushing system is recommended when metering the flow of liquids containing gritty materials or heavy concentration of solids. This system introduces a small continuous back flow of clear water into the propeller hub, thus preventing the solids-bearing liquid from reaching the propeller shaft bearing. The Builders Sightflo Indicator in this system gives a visual indication that the back flow is adequate and is properly maintained. (See Fig. 1)

The Propeller

The propeller type meter, as illustrated in Figs. 2 and 3, is made up of a 6-blade propeller, approximately 8/10 of the internal pipe diameter mounted transversely in the center of the pipe. The propeller is made of plastic material, having a specific gravity of approximately 1, and is suitable for use in either cold water or hot water, up to 250° F. For special liquids the plastic propeller may be replaced by an aluminum propeller, or stainless steel propeller,

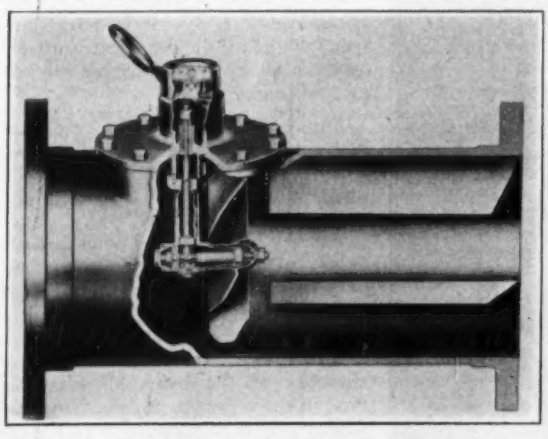


Fig. 2—Cutaway view of Sparling propeller meter
(Note the flow-straightening vanes)

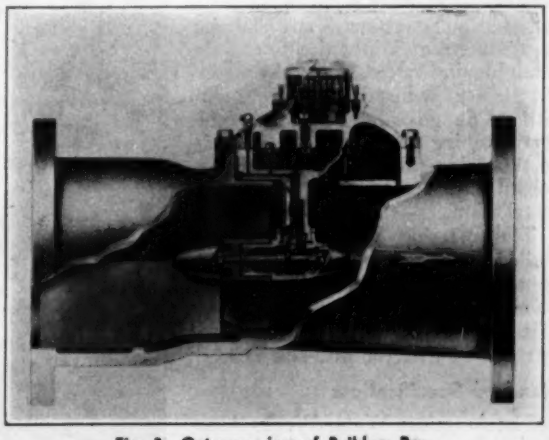


Fig. 3—Cutaway view of Builders Propeloflo meter
(Note the Venturi design and streamlined nose of propeller mechanism)

depending upon requirements. The propeller, when made of plastic, practically displaces its own weight in water and is mounted on ball bearings, which allow it to rotate freely in the stream of water.

Installation

The metering element may be installed directly on an existing pipe line by means of a saddle either bolted or welded directly on the main. In such installations it is important that the inside diameter of the pipe be accurately determined and the meter properly centered. In all installations the meterhead may be removed from the pipe line very quickly and easily, and it is normally good practice to make a yearly inspection.

In selecting the proper location for the metering element it should be kept in mind that a normal flow of water, free from either spiraling or jet action, is required for accurate results. The spiraling effect which may be caused in the flow of water passing through a series of elbows, can be largely corrected by installing straightening vanes in the line preceding the meter.

Various forms of such vanes are in use, but a very simple and effective correction may be made by the installation of 3 vanes, each approximately ⅓ the pipe diameter, and 2½ pipe diameters long, set at 120 degrees to each other in the pipe. These vanes will not eliminate a disturbance caused by a partially opened gate valve, but are effective for double elbows or other standard fittings, and with such vanes the manufacturers state that the meter element may be installed with but five pipe diameters of straight approach. However, when possible, a longer section of straight approach is desirable.

A straight run of one pipe diameter downstream from the meter is normally sufficient for all installations. It is always good practice to use the straightening vanes. When the metering element is installed complete with either a flange or bell and spigot tube, straightening vanes are mounted directly inside this metering section to constitute a complete unit, ready for installation.

The metering element may be installed in either a vertical or horizontal pipe and it may be mounted on either the suction or discharge side of a centrifugal pump. In all cases it is required that the line run full.

Standard Specifications

The American Water Works Association has published standard specifications for cold water meters—current type, propeller-driven—known as No. 7M5-T. These cover general description, capacity, size, design, connections, operating mechanism, and notes of special importance.

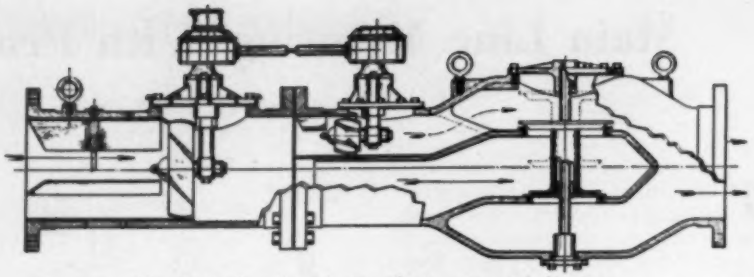


Fig. 4—Section through propeller-type compound meter
(Note valve which closes on low flows to cause entire flow to pass through small meter.)

Calibration

Experiments and experience have shown that a propeller will rotate in direct proportion to the velocity of water in a pipe at all flows above an approximate pipe velocity of ½ linear foot per second. The index, or number of cubic feet passing through the pipe for each turn of the meter shaft, is determined from volumetric tests. From this index proper gears are furnished for direct totalization of the flow.

Compound Design

Fig. 4 is a sectional illustration of a compound meter suitable for use where an extremely wide range of flow measurement is required. This is offered by the Sparling Meter Co., of Los Angeles, and has a range of 150:1. A compound unit consists chiefly of two propeller type meters working in series through a pair of ratchet clutches, allowing the meter revolving at the highest speed to drive the totalizer-register. On a very low flow the large meter will under-register, and thus allow the small meter to drive the totalizer. As the flow increases a pipe velocity is reached where the large meter has come in step and the small meter is operating at a high capacity. At this point the pressure loss caused by the small meter operating on the differential area of the compounding valve forces the valve to lift itself and allow the higher flow to by-pass the small meter.

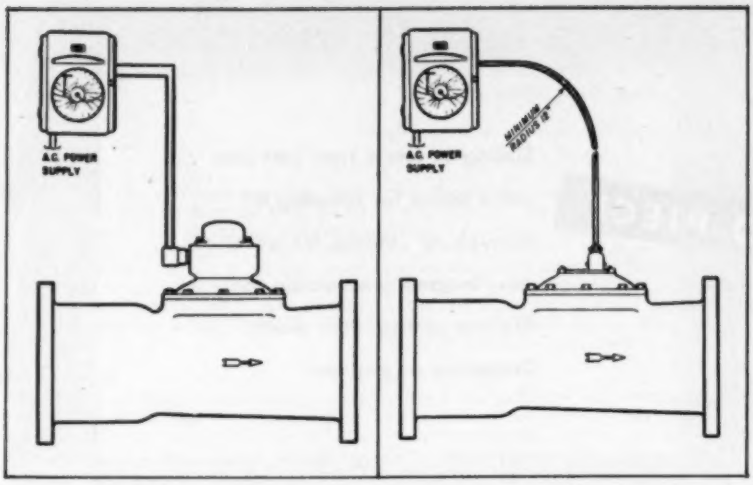
Although the minimum flow is considerably above that of the standard domestic *compound* meter, it is well adapted for main line measurement as the pressure loss caused by the entire unit does not normally exceed 2 pounds at maximum flow.

Fig. 5—Typical Sparling indicator-recorder of the mercury governor type

Indicating and Recording Elements

A rate-of-flow indicating and recording instrument may be used in conjunction with the straight totalizing primary element. The primary step of a current type meter is direct totalization. If the rate-of-flow indication is desired it must be obtained through a secondary step normally involving either a governor bowl or a friction plate revolving at a constant speed with a follower locating itself on the plate by impulses from the primary element.

Figure 5 illustrates the recording instrument involving a governor bowl which is driven either mechanically up to 15 feet from the metering element, or electrically to any distance required. The governor bowl consists chiefly of a float riding in the center of a mercury well. As the governor revolves, the mercury, through centrifugal force, finds its way through a small needle-valve to the outer chamber of the bowl, allowing the float in the center to have a rising and falling action in proportion to the revolving speed of the bowl. This type of governor is effective over approximately a 6-to-1 range and is extreme-



TOTALIZER-INDICATOR-RECORDER
(Electrically-Operated)

TOTALIZER-INDICATOR-RECORDER
(Flexible Shaft Electrically-Operated)

Fig. 6—Diagrams of arrangement for remote totalizer-indicator-recorder (Left—electrically operated; Right—cable electric operated)

ly simple and well suited for normal flow measurement.

A recording instrument utilizing the revolving friction plate, with a follower locating itself by impulses from the metering element, as mentioned above, produces a straight line of rate indication over approximately 25-to-1 range and is well suited for recording flows of main distribution or consumption lines.

Recorders can be adapted to show the combined flows of two or more pipe lines and combinations may be furnished showing the net total of several lines where the flow of any one pipe may be in either forward or reverse direction.

Electrically operated totalizer-indicator-recorders make possible the transmission of liquid flow metering information over any distance (See Fig. 6). A simple two-wire circuit carries the impulse from a transmitter at the Builders Propeloflo meter to the remotely located receiving instrument. Similar remote operation is available for the Sparling meter.

Flexible cable operated totalizer-indicator-recorders (See Fig. 6) permit transmission of liquid flow metering information to any point within a 25-ft. radius of the propeller type meter. In the case of the Builders Propeloflo meter, the flexible cable is connected to the meter either by a straight-type adapter plate or by a right angle take-off. At the receiving instrument, the connection is made through a coupling unit which can be positioned for straight line approach of the cable to the instrument.

Application With Chemical Feeders

Automatic pacing of chemical feeders, by either mechanical or electrical means, is readily obtainable from a current meter element as the shaft of the meter is revolving in direct proportion to the flow and considerable load may be applied without affecting the rotating speed of the propeller.

If given the periodic inspection required by any primary metering element, the characteristic of low pressure loss and accuracy over a wide range of flow allows the principle of the current meter to fill an important part in the water works field.

The propeller-type meter is not suitable for measuring raw sewage and is not generally recommended for measurement of a sewage effluent unless the effluent has passed through a filter bed. When installing such meters on raw water gravity lines, care must also be taken to provide screens at the inlet structure to prevent excessive algae or weeds from passing down the pipe and fouling the meter propeller.

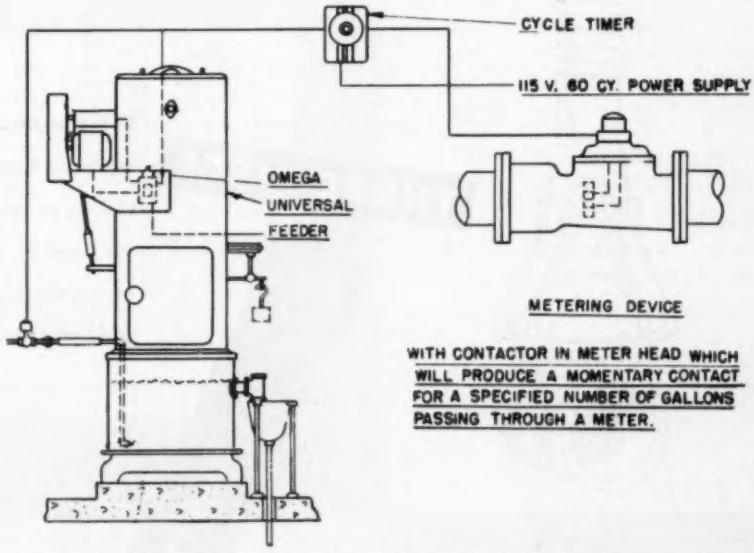

CYCLE TIMER
115 V. 60 CY. POWER SUPPLY
OMEGA
UNIVERSAL
FEEDER
METERING DEVICE
WITH CONTACTOR IN METER HEAD WHICH WILL PRODUCE A MOMENTARY CONTACT FOR A SPECIFIED NUMBER OF GALLONS PASSING THROUGH A METER.

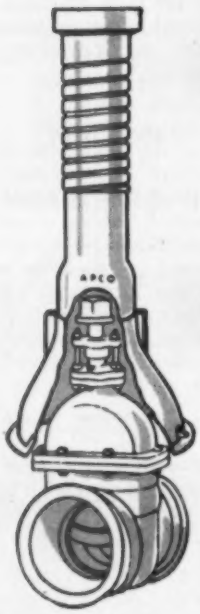
Fig. 7—Propeloflo meter used to pace proportional chemical feeding

TWO PIECE

Sliding or screw type cast iron valve boxes for covering 4" through 10" valves for water or gas. Rugged construction for lifetime service. 5¼" shaft. Extensions as required.

Adjustable VALVE BOXES

APCO



THREE PIECE

Valve boxes supplied with separate bases are available in sliding or screw type. Made with 5¼" and 7" shafts with extensions as required. Also, a complete line of service and roadway Boxes.

We invite inquiries to our nearest sales office

122 So. Michigan Avenue
Chicago 3, Ill.

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General Sales Offices

ANNISTON, ALABAMA

ALABAMA PIPECOMPANY

ANNISTON **ALABAMA**

Standard Design for Water Services

By MARSDEN C. SMITH

Chief Engr., Dept. of Public Utilities, Richmond, Va.

WHAT is the standard pressure, and what size service does the local water utility require? The tables and figures of this article have been proved by several years' use in at least one large city to be a relatively simple and highly successful means of determining the proper size of water services for most practical conditions.

Basis of Design

The basis of design is a pressure loss between the main and the most remote outlet of 11.3 psi.; of which the service and meter are allocated 7.0 psi. Assuming the water system to be operated so that a minimum of 35 psi. at street level is maintained at all points in the street mains; then this design will provide an outlet flowing pressure of 4.3 psi. (10 ft.) at an elevation of 44.7 ft. above the street level.

This is always adequate for the normal three-story building. But even where pressures in the main are greater than 35 psi. at street level, it is usually unwise to design services smaller than those required by these tables and graphs.

The "load factor multiplier" is used to take into account the fact that not all outlets being served are used at the same time. Of course, the laws of probability recognize that such factors will be exceeded. Yet experience proves these to be remarkably accurate in that the services are of a reasonable size and yet the frequency of overload is so low that no service so designed has had to be enlarged.

Meters

For services of normal length it is less expensive to reduce friction loss by enlarging the pipe than by enlarging the meter. For this reason, meters are rarely used in pipes of their nominal size.

Of course, it must be remembered that an overloaded meter is subject to excessive wear. For this reason, except in unusual applications, the meter should be of such size that the quantity of water found by the tables to be the estimated flow should not cause a greater loss than 5 psi. through the meter. For example, a 3-inch compound meter should not be used for flows in excess of 190 gpm., unless it is known that more than that quantity will be required only at rare intervals. The entire 7 psi. friction loss allocated to both the meter and pipe will be consumed in this meter alone at 217 gpm. flow.

Service Length

Since the pressure loss in a service is a function of the distance that water must be carried in the service, as well as of flow, the length of each service must be known if a correct design is to be made. The distance used in these tables is from the main in the street to the first "riser" from the service pipe. (Sill cocks are not considered to be a "riser".) The risers are then designed to permit a friction loss of not more than 4.3 psi. from the service pipe to the most remote outlet.

Method of Use of Tables

The use of the tables for residential services is simply a matter of knowing the equipment to be served and the service length, and then selecting the proper combination of meter and pipe size from Table I or Table II depending on whether tank toilets or flushometers are used. For a residential service whose exact equipment cannot be found in the tables, interpolations can, as a rule, be readily made.

TABLE I

Meter and Pipe Sizes for Residences Using Tank Toilets

Group No.	Fixtures Proposed or Installed	Size of Service*	Length Range	Size of Service*	Length Range
		in.	ft.	in.	ft.
1.	1 toilet, 1 hydrant	⅝ × ¾	to 225		
2.	1 toilet, 1 kitchen sink	⅝ × ¾	to 105	⅝ × 1	106–280
3.	1 bath, 1 kitchen sink	⅝ × ¾	to 95	⅝ × 1	96–190
4.	1 bath, 1 kitchen sink, 1 furnace, 1 or more sill cocks†	⅝ × ¾	to 95	⅝ × 1	96–170
5.	1 bath, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 extra lavatory and toilet	⅝ × ¾	to 45	⅝ × 1	46–150
6.	2 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks	⅝ × ¾	to 45	⅝ × 1	46–130
7.	2 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 extra lavatory and toilet	⅝ × 1	to 110	⅝ × 1¼	111–300
8.	3 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks	⅝ × 1	to 95	⅝ × 1¼	96–275
9.	3 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 laundry tub	⅝ × 1	to 90	⅝ × 1¼	91–185
10.	3 baths, 2 kitchen sinks, 1 furnace, 1 or more sill cocks, 1 laundry tub	⅝ × 1	to 55	⅝ × 1¼	56–100
11.	3 baths, 2 kitchen sinks, 1 furnace, 1 or more sill cocks, 2 laundry tubs	⅝ × 1¼	to 50	1 × 1¼	51–195
12.	3 baths, 2 kitchen sinks, 1 furnace, 1 or more sill cocks, 2 laundry tubs, 1 extra lavatory and toilet	1 × 1¼	to 85	1 × 1½	86–175
13.	1 bath, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 laundry tub	¾ × ¾	to 55	¾ × 1	56–160
14.	1 bath, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 extra lavatory and toilet, 1 laundry tub	¾ × ¾	to 45	¾ × 1	46–130
15.	2 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 laundry tub	¾ × ¾	to 45	¾ × 1	46–130
16.	2 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 extra lavatory and toilet	¾ × 1	to 110	¾ × 1¼	111–300
17.	3 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 laundry tub	¾ × 1	to 95	¾ × 1¼	96–275

*Size of meter used, with larger size service pipe.
†Built-in lawn sprinklers are not included with sill cocks.

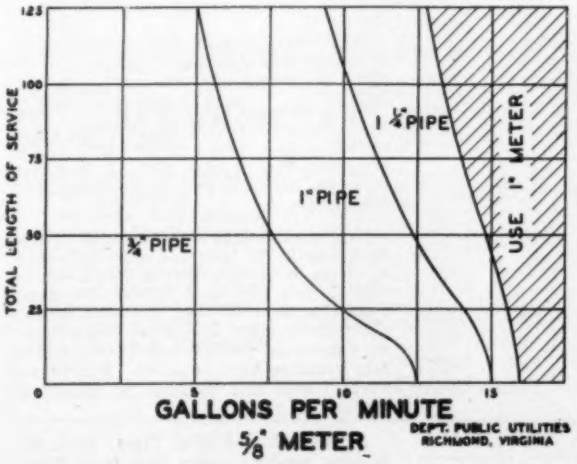


Figure 1

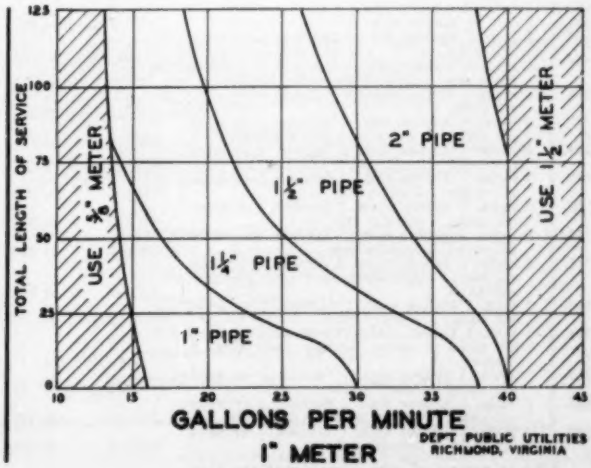


Figure 2

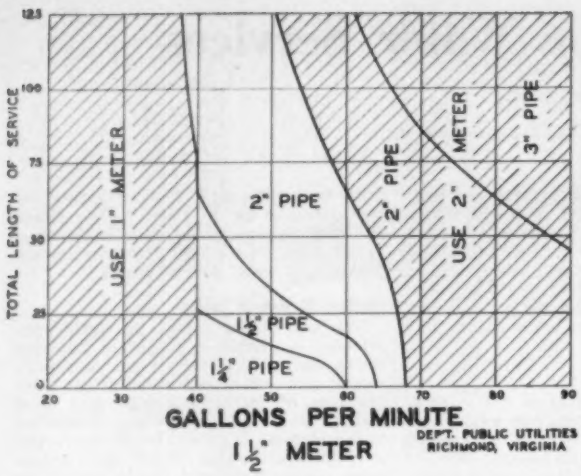


Figure 3

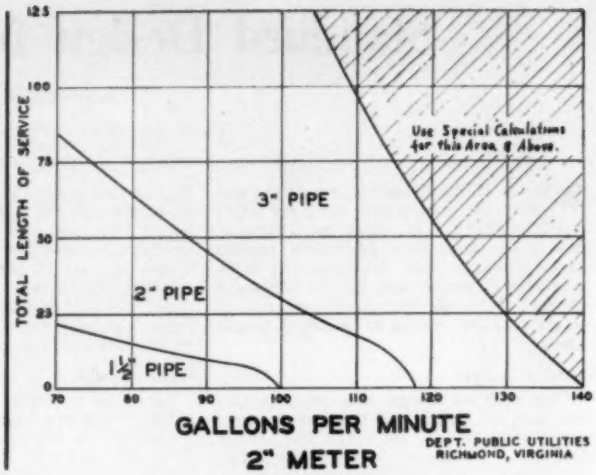


Figure 4

Because of the higher frequency of use of outlets in apartments than in single or two-family premises, a somewhat larger service for apartments (and also for industrial or commercial use) is required. For use in these cases Tables III and IV and Figs. 1, 2, 3, and 4 have been prepared.

The four charts, Figs. 1, 2, 3, 4, show the size of meter to be used for different rates of flow through different lengths of service.

Example 1: An apartment structure contains twelve apartments and each apartment contains a bath with tub equipped with shower, a lavatory and a flushometer toilet, also a kitchen sink. The basement contains two laundry tubs, one slop sink, one furnace, one lavatory, one flushometer toilet, and two sill cocks.

The first step is to determine the total flow required for these fixtures. Referring to Table III the following data are developed.

TABLE III

Demand and Load Factor of Various Appliances

Appliance	Number of outlets	Gal. per minute
Domestic kitchen sinks	2	5
Commercial kitchen sinks	2	7
Shower or shower and tub combined	2	6
Tub or tub and shower combined	2	6
Lavatory	2	4
Tank Toilet	1	4
Bath	5	14
Domestic laundry tubs	1	3
Sill cocks	1 (Max.)	3 (Max.)
Furnace connections	0	0
Steam table sinks	1	6
Soup kettles	2	20
Coffee urns	1	5
Potato peeler	1	8
Dish washer	2	8
Glass washer	2	6
Slop sinks	1	3
Drinking fountains	0	0

The flow of water to Flushometer toilets and urinals should be determined separately from the standard appliances and added thereto in accordance with the following schedule:

No. of Units	Toilet gpm.	Urinal gpm.	No. of Units	Toilet gpm.	Urinal gpm.
1 to 2	30	2	39 to 60	65	7
3 to 4	40	3	61 to 100	70	8
5 to 7	45	4	101 to 141	75	8
8 to 10	50	4	142 to 190	80	9
11 to 15	55	5	191 to 240	85	10
16 to 38	60	6	241 to 400	90	10

TABLE II

Meter and Pipe Sizes for Residences Using Flushometer Toilets

Group No.	Fixtures Proposed or Installed	Size of Service*	Length Range	Size of Service*	Length Range
		in.	*ft.*	*in.*	*ft.*
101.	1 toilet, 1 hydrant	1×1½	to 115	1×2	116–300
102.	1 toilet, 1 kitchen sink	1×1½	to 115	1×2	116–300
103.	1 bath, 1 kitchen sink	1×1½	to 105	1×2	106–280
104.	1 bath, 1 kitchen sink, 1 furnace, 1 or more sill cocks†	1×1½	to 105	1×2	106–280
105.	1 bath, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 extra lavatory and toilet	1×1½	to 75	1×2	76–145
106.	2 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks	1×1½	to 75	1×2	76–145
107.	2 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 extra lavatory and toilet	1½×2	to 200		
108.	3 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks	1½×2	to 200		
109.	3 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 laundry tub	1½×2	to 200		
110.	3 baths, 2 kitchen sinks, 1 furnace, 1 or more sill cocks, 1 laundry tub	1½×2	to 200		
111.	3 baths, 2 kitchen sinks, 1 furnace, 1 or more sill cocks, 2 laundry tubs	1½×2	to 200		
112.	3 baths, 2 kitchen sinks, 1 furnace, 1 or more sill cocks, 2 laundry tubs, 1 extra lavatory and toilet	1½×2	to 160		
113.	1 bath, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 laundry tub	1×1½	to 75	1×2	76–145
114.	1 bath, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 extra lavatory and toilet, 1 laundry tub	1×1½	to 75	1×2	76–145
115.	2 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 laundry tub	1×1½	to 75	1×2	76–145
116.	2 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 extra lavatory and toilet	1½×2	to 200		
117.	3 baths, 1 kitchen sink, 1 furnace, 1 or more sill cocks, 1 laundry tub	1½×2	to 200		

*Size of meter used, with larger size service pipe.
†Built-in lawn sprinklers are not included with sill cocks.

Fixtures	Outlets	Flow
12 Tubs	24	72
13 Lavatories	26	52
12 Kitchen sinks	24	60
2 Laundry tubs	2	6
1 Slop sink	1	3
1 Furnace connection	0	0
2 Sill cocks	1	3
	78	196

Now from Table IV, find multiplier for 78 outlets to be 0.28, or 196 × 0.28 = 54.88 gpm., the estimated flow.

From the same Table IV it is found that 13 flushometer toilets require 55.0 gpm. estimated flow. This must be added to the estimated flow of 54.88 gpm. for fixtures, or a total of 109.88 gpm. is to be used for the design.

Now assume that from the main to the first riser is 110 feet; and refer to Figure 4. Here it is seen that a 2-inch meter with 3-inch pipe will deliver 110 gpm. somewhat over 93 feet. If location assures more than 35 psi. in main; that service design would be used even for 110 feet distance here required. But in no event would this distance be increased beyond 121 feet.

Example 2: Industrial Plant. First determine sanitary water flow from Table III:

		Fixture	Flow
20	Showers	40	120
5	Wash Stands @ 6 gpm. each	5	30
30	Toilets (tank)	30	120
20	Urinals @ ½ gpm.	0	10
7	Hose connections	1	3
		76	283

From Table IV, the load factor for 76 fixtures is determined to be 0.28.

$$283 \times .28 = 79.24 \text{ gpm.}$$

Now determine cuisine flow, also from Table III:

3	Soup kettles	6	60
2	Coffee urns	2	10
2	Dish washers	4	16
4	Kitchen sinks	8	28
6	Slop sinks	6	18
10	Drinking fountains	0	0
		26	132

The load factor for 26 fixtures (Table IV) is 0.32.

$$132 \times .32 = 42.24 \text{ gpm.}$$

Now since sanitary flow will not normally be a maximum when industrial and cuisine is a maximum, it is advisable to further reduce this, as long as industrial flow is greater than calculated sanitary flow. And so:

Sanitary flow = 79.24 × .5 =	39.62 gpm.
Cuisine flow =	42.24 "
Industrial flow =	175.00 "
Total design flow	256.86 "

This requires a 4-inch meter and a 4-inch pipe up to 100-foot service length. But a 6-inch pipe would be strongly urged even for a lesser distance than 100 feet.

TABLE IV
Multiply for Load Factor

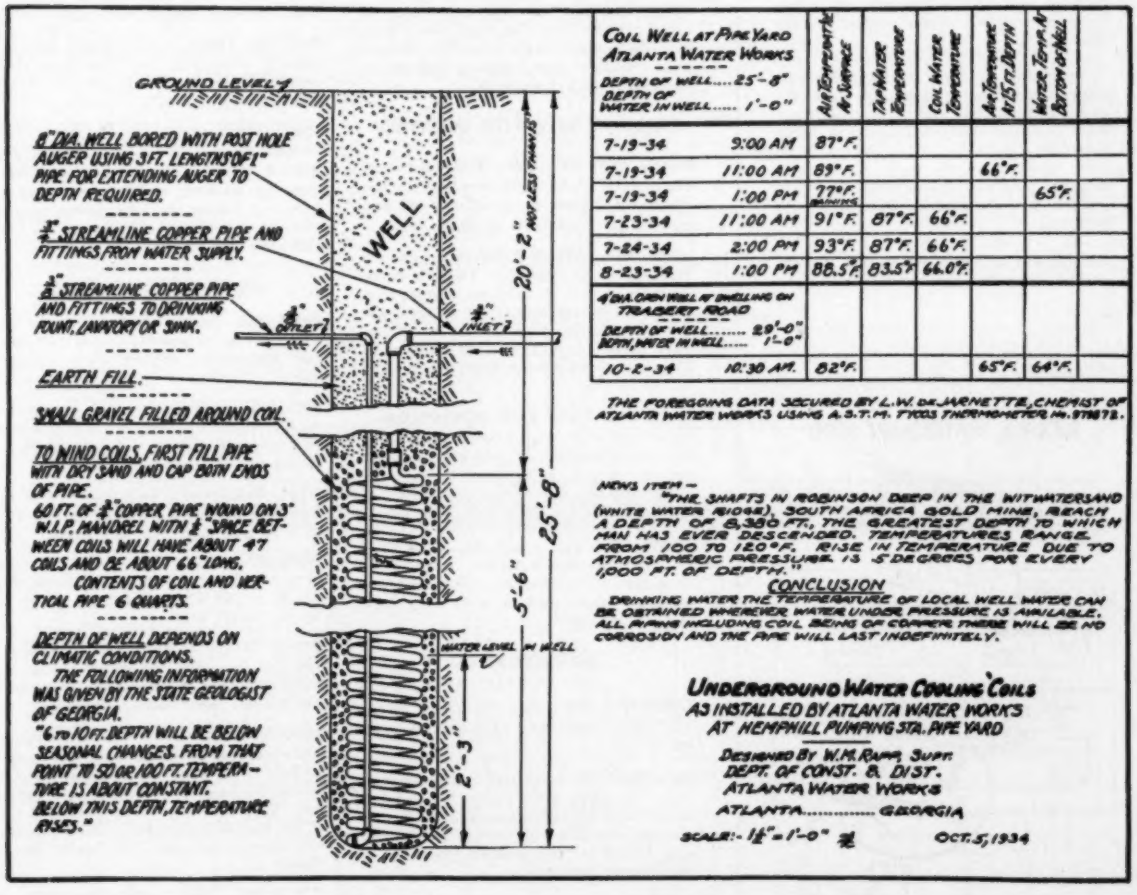
Total No. of outlets	1	2	3	4	5	6	7	8	9
Multiplier	1	.75	.635	.575	.52	.465	.415	.375	.345
10	11	12	13	14	15	16	17	18	19	20
.32	.30	.28	.26	.25	.24	.23	.22	.22	.21	.22
21	22	23	24	25	26	27	28	29	30	32
.22	.24	.26	.28	.30	.32	.33	.33	.34	.34	.34
34	36	38	40	42	44	46	48	50	55	60
.34	.34	.34	.34	.34	.34	.34	.34	.33	.32	.31
65	70	75	80	85	90	95	100	More than 100		
.30	.29	.28	.27	.26	.25	.24	.23	.22		

Notes:

In using these tables and graphs, the following data should be kept in mind.

1) Pipe friction, ¾-inch to 2-inch inclusive C = 130 (copper); 3-inch and above C = 100 (cast iron).
2) Meters used, ⅝ to 2-inch, disc; 3-inch and above, compound.
3) Flow for 5 psig. loss in meter used is ⅝ = 14.5 gpm.; 1-inch = 38 gpm.; 1½-inch = 68 gpm.; 2-inch = 119 gpm.; 3-inch = 188 gpm.; 4-inch = 340 gpm.; 6-inch = 720 gpm.; 8-inch = 1300 gpm.; 10-inch = 1700 gpm.

UNDERGROUND WATER COOLING SCHEME OF ATLANTA WATER DEPARTMENT


GROUND LEVEL
8" DIA. WELL BORED WITH POST HOLE AUGER USING 3 FT. LENGTHS OF 1" PIPE FOR EXTENDING AUGER TO DEPTH REQUIRED.
¾" STREAMLINE COPPER PIPE AND FITTINGS FROM WATER SUPPLY.
¾" STREAMLINE COPPER PIPE AND FITTINGS TO DRINKING FOUNT, LAVATORY OR SINK.
EARTH FILL.
SMALL GRAVEL FILLED AROUND COIL.
TO WIND COILS, FIRST FILL PIPE WITH DRY SAND AND CAP BOTH ENDS OF PIPE.
60 FT. OF ¾" COPPER PIPE WOUND ON 3" W.I.P. MANDREL WITH ¾" SPACE BETWEEN COILS WILL HAVE ABOUT 47 COILS AND BE ABOUT 66" LONG.
CONTENTS OF COIL AND VERTICAL PIPE 6 QUARTS.
DEPTH OF WELL DEPENDS ON CLIMATIC CONDITIONS.
THE FOLLOWING INFORMATION WAS GIVEN BY THE STATE GEOLOGIST OF GEORGIA.
"6 TO 10 FT. DEPTH WILL BE BELOW SEASONAL CHANGES. FROM THAT POINT TO 50 OR 100 FT. TEMPERATURE IS ABOUT CONSTANT. BELOW THIS DEPTH, TEMPERATURE RISES."
WELL
OUTLET
INLET
20'-2" APPLIES THAN 15'
25'-8"
5'-6"
2'-3"
WATER LEVEL IN WELL

COIL WELL AT PIPE YARD ATLANTA WATER WORKS DEPTH OF WELL..... 25'-8" DEPTH OF WATER IN WELL..... 1'-0"		AIR TEMPERATURE AT SURFACE	TAP WATER TEMPERATURE	COIL WATER TEMPERATURE	AIR TEMPERATURE AT BOTTOM OF WELL	WATER TEMP. AT BOTTOM OF WELL	
7-19-34	9:00 AM	87°F.					
7-19-34	11:00 AM	89°F.			66°F.		
7-19-34	1:00 PM	77°F. RAINING				65°F.	
7-23-34	11:00 AM	91°F.	87°F.	66°F.			
7-24-34	2:00 PM	93°F.	87°F.	66°F.			
8-23-34	1:00 PM	88.5°F.	83.5°F.	66.0°F.			
4" DIA. DRIVEN WELL AT DWELLING ON TRABERT ROAD DEPTH OF WELL..... 29'-0" DEPTH, WATER IN WELL..... 1'-0"							
10-2-34	10:30 AM.	82°F.			65°F.	64°F.	

THE FOREGOING DATA SECURED BY L. W. DE JARNETTE, CHEMIST OF ATLANTA WATER WORKS USING A.S.T.M. TYPE THERMOMETER No. 91787B.

NEWS ITEM —
"THE SHAFTS IN ROBINSON DEEP IN THE WITWATERSAND (WHITE WATER RIDGE), SOUTH AFRICA GOLD MINE, REACH A DEPTH OF 8,380 FT., THE GREATEST DEPTH TO WHICH MAN HAS EVER DESCENDED. TEMPERATURES RANGE FROM 100 TO 120°F. RISE IN TEMPERATURE DUE TO ATMOSPHERIC PRESSURE IS 5 DEGREES FOR EVERY 1,000 FT. OF DEPTH."

CONCLUSION

DRINKING WATER THE TEMPERATURE OF LOCAL WELL WATER CAN BE OBTAINED WHEREVER WATER UNDER PRESSURE IS AVAILABLE. ALL PARTS INCLUDING COIL BEING OF COPPER, THERE WILL BE NO CORROSION AND THE PIPE WILL LAST INDEFINITELY.

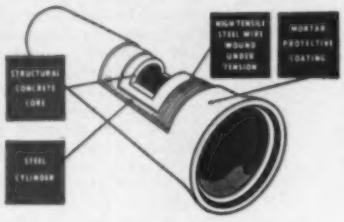
UNDERGROUND WATER COOLING COILS
AS INSTALLED BY ATLANTA WATER WORKS
AT HEMPHILL PUMPING STA. PIPE YARD

DESIGNED BY W. M. RAPP, SUPT.
DEPT. OF CONST. & DIST.
ATLANTA WATER WORKS
ATLANTA..... GEORGIA
SCALE:- 1½" = 1'-0" OCT. 5, 1934

PRESTRESSED CONCRETE STEEL-CYLINDER PIPE

AWWA Spec. C301-52

PRICE BROTHERS COMPANY, P. O. Box 825, DAYTON 1, OHIO



Prestressed Pipe was designed by research and structural engineers from a *combination* of materials, each to do a specific job, and to provide a *combination* of advantages found in no other pipe.

A *steel cylinder* to provide water tightness and high beam strength.

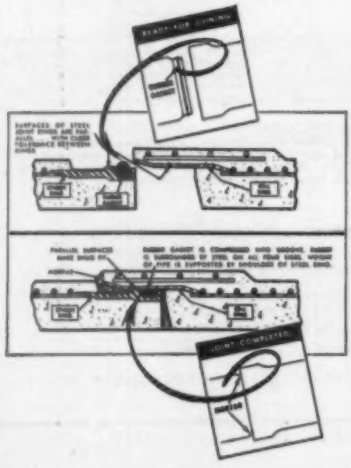
A *centrifugally spun* structural concrete core to give permanent and sustained high flow without tuberculation or corrosion.

A wrapping of *high tensile steel* wire under tension to prestress the steel cylinder and concrete core thus permitting high pressure without tension in these materials.

A rubber and zinc coated steel *expansion joint* to provide flexible, watertight connections.

An outside encasement of *rich cement mortar* to protect the entire waterline.

FLEXIBLE, WATERTIGHT JOINT



HOW PRESTRESSED CONCRETE STEEL-CYLINDER PIPE MEETS THE REQUIREMENTS FOR A WATER LINE

LIFE EXPECTANCY

SOIL ACTION—On Price Prestressed Pipe only concrete is exposed both inside and out. Concrete is "at home" in the ground. It cannot rust or corrode, and almost always actually gets harder and stronger the longer it is underground. Underground concrete water lines in Mexico and France are still in excellent condition after hundreds of years.

ELECTROLYSIS—Price Pipe has never been affected by electrolysis.

STRENGTH

BEAM STRENGTH—The steel cylinder encased inside Price Pipe and the structural concrete core provide an exceptionally high beam strength.

BURSTING STRENGTH—The combination of a steel cylinder, prestressed high tensile steel wire and concrete make Price Pipe shatterproof. Sudden and complete failure or bursting is all but impossible.

GALLONS OF WATER DELIVERED

INITIAL RATE OF FLOW—With Prestressed Pipe, water flows over concrete, which equals the highest flow coefficient of *any* pressure pipe structural material.

LONG TERM RATE OF FLOW—Concrete not only retains its high "C" value, it often increases because of a slippery surface that forms on the concrete. Tests in Louisville show an increase from a "C" of 145 in 1931 to a "C" of 149 in 1948. Tests in Denver show an increase from 141 in 1925 to 150 in 1943.

TUBERCULATION AND CORROSION—Under ordinary circumstances Price Pipe will never corrode or tuberculate. After years of service, it will have exactly the same diameter and be just as smooth as when installed.*

JOINTS—The rubber and zinc-coated steel joint on Price Pipe is *flexible*. It can adjust to expansion, contraction, vibrations and settling without leaking even with high internal pressures.

MAINTENANCE

CLEAN OUT—Price Pipe will neither tuberculate or corrode, and will require no cleaning out.

RELINING—The structural concrete core of Price Pipe serves as its lining. It is held in compression by the wrapping of high tensile steel wire and is an integral part of the pipe. It does not chip or disintegrate. Relining is never required.

BLOW UPS—Blow ups and resulting floods are all but impossible with Price Pipe. Its design makes it shatterproof.

TAPPING — Any water-works serviceman can tap Price Pipe, under pressure, using regular type, long travel tapping machine, with a carboloy tipped cutter. The design of the tap actually makes the pipe *stronger* at the point of the tap.

COST

ORIGINAL COST—Price Pipe, in spite of its long life, sustained capacity and great strength costs no more than other types of water pipe. Under certain conditions it may even be considerably less.

INSTALLATION — On most installations a back hoe both digs the trench and lays Price Pipe, resulting in speed and low cost. This is because of the self-centering joint on which steel takes the backload and rubber forms the seal. Contractors generally bid lower on the installation of Price Pipe than any other type of water pipe.

PUMPING COSTS — Price Pipe's flow coefficient *stays* high and the bore stays smooth. Pumping costs do not rise as they do with some pipes.

LONG TERM COST — Here's where Prestressed Pipe really shines. Add to low original cost the advantages of no cleanouts, no relining, no blow ups, absolute minimum leakage, and lower pumping costs, plus the permanency of concrete . . . then you have *true* economy.

YOUR REQUIREMENTS

PRESSURES—Prestressed Pipe can be designed for any pressure common to American waterworks practice with adequate reserve strength for normal overloadings.

SPECIALS — Connections and fittings are readily available. They are manufactured of reinforced concrete and custom tailored to the design requirements.

SIZES—Prestressed Pipe is available in 16-foot lengths and in diameters of 16″, 20″, 24″, 30″, 36″, 42″, 48″ and larger.

DELIVERY — Price Pipe is available from plants in Dayton, Ohio, and Miami, Fla. On large jobs a portable plant can be set up on the job site.

OTHER TYPES OF CONCRETE PIPE—Price Brothers Co. also manufactures Concrete Steel Cylinder Pipe, Not Prestressed; Subaqueous, Sewer and Culvert Pipe.

INFORMATION — Price Brothers engineers know pipe line problems. They will be glad to help in any way they can, without obligation. For booklets on Manufacture, Laying and Tapping, write Price Brothers Co., P. O. Box 825, Dayton 1, Ohio. For general information mail the Reader Service Card.

* In isolated instances, but not common in America; algae and sponge formations will collect on the inside of all types of water lines. Rare soil conditions may affect the permanence of *any* pipe material.

Chlorination to Restore Aqueduct Capacity

San Diego finds programmed chlorine application effective and economical

By LEE STREICHER

Chief Chemist, Metropolitan Water Distr. of Southern Calif., LaVerne, California

DOMINANT among the factors which are reflected in the past history and which control the future growth of southern California is the struggle for water. Located in a semi-arid section of the United States, this region has too little rainfall to provide for the needs of its agricultural, industrial and urban areas. Only by drawing upon the once tremendous supply of underground water accumulated over thousands of years has the phenomenal growth of this area been made possible. With the continuing growth in population and industry, the draft on the underground water reserve has increased until it now exceeds the replacement by many million gallons of water each day. Where feasible, storage reservoirs have been constructed in an effort to conserve and utilize to a maximum the limited and variable water supplies available from the upland and mountain streams. These have long since proved wholly inadequate to meet the constantly increasing demands for water. Even in San Diego County, where for many years the waters impounded during wet seasons provided satisfactorily for the demands during subsequent dry periods, the present use of water is about 25 per cent greater than the safe yield of these impounding reservoirs.

The only logical solution to this problem lay in the importation of sufficient water from a dependable, adequate and reasonably close source to provide for present needs and those of the forseeable future. The Colorado River was such a source.

Metropolitan Water District Formed in 1927

In 1927 the Metropolitan Water District Act was adopted by the California legislature and in 1928 the Metropolitan Water District of Southern California was organized to bring in the water of the Colorado River. The voters of the cities comprising the District authorized a bond issue to finance the construction of the now famed Colorado River Aqueduct and all necessary appurtenances to bring Colorado River water to these cities and contiguous areas, the whole project to be paid for solely by the taxpayers and water users of the District. Construction of the aqueduct was started in 1932, and the first water was delivered in Los Angeles metropolitan area in June, 1941. [a, 3]

Wartime augmented demands pinpointed the critical water shortage in the San Diego area. By agreement with the other Southern California agencies concerned, the city and/or county had already been apportioned an annual quota of 112,000 acre feet of Colorado River water, but no facilities were available for delivery of any of this to the vicinity of San Diego. In December of 1944 President Roosevelt approved an emergency appropriation for construction of an aqueduct from the west portal of San Jacinto tunnel (on the Colorado River Aqueduct) to San Vicente reservoir of the San Diego water system—(Fig. 2). Although some delay in construction was occasioned by an acute shortage of labor and materials, the initial flow of Colorado River water passed through this vital link into San Vicente reservoir on November 24, 1947. Design and construction of this aqueduct was under Navy supervision.

On December 17, 1946, the corporate area of the San Diego County Water Authority officially became annexed to the Metropolitan Water District of Southern California. The District assumed payment of one half the cost of construction of the San Diego Aqueduct and, upon completion

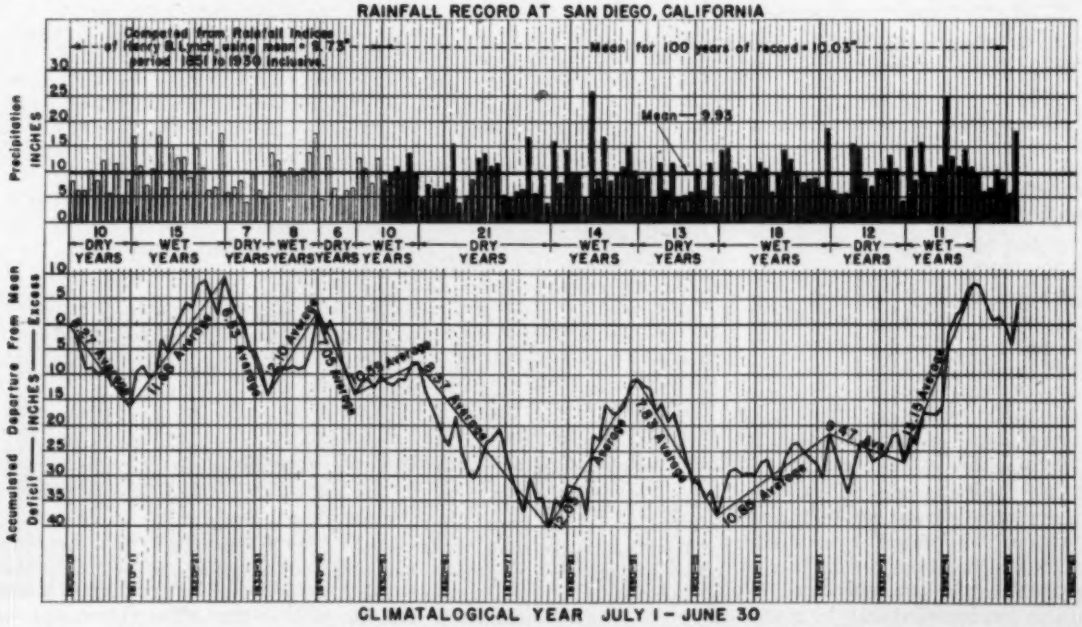

RAINFALL RECORD AT SAN DIEGO, CALIFORNIA
Computed from Rainfall Indices of Henry B. Lynch, using mean = 9.73" period 1851 to 1930 inclusive.
Mean for 100 years of record = 10.03"
Precipitation INCHES
Mean — 9.95
10 DRY YEARS
15 WET YEARS
7 DRY YEARS
8 WET YEARS
6 DRY YEARS
10 WET YEARS
21 DRY YEARS
14 WET YEARS
13 DRY YEARS
18 WET YEARS
12 DRY YEARS
11 WET YEARS
Accumulated Departure From Mean Deficit — INCHES — Excess
CLIMATALOGICAL YEAR JULY 1 – JUNE 30

Fig. 1—RAINFALL record at San Diego, Calif., 1800-1953 reveals 100 yr. mean of but 10.03 inches.

Fig. 2—AQUEDUCT of San Diego County Water Authority
Point of chlorine application San Jacinto Regulating Reservoir near head of aqueduct.

of the line, took over operation of the northerly one half of the system.

Aqueduct Design Features and Operating Characteristics

The first barrel of the San Diego Aqueduct (Fig. 2) designed for an initial capacity of 85 cubic feet per second, is 71.1 miles long and consists of 4.4 miles of 72-inch diameter tunnel; 2.0 miles of 96-inch and 12.4 miles or 72-inch diameter reinforced concrete pipe; 21.8 miles of 54-inch and 28.8 miles of 48-inch diameter precast concrete pipe; 1.1 miles of steel pipe; and a regulating reservoir with available storage of 1400 acre feet 0.6 mile in length located two miles from the takeout at San Jacinto tunnel. When the aqueduct was designed, it was intended that the capacity would be increased ultimately to 165 c.f.s. Because of the subnormal rainfall in this area in recent years and the increasing demand for water, the second barrel is already under construction.[10]

Early in December, 1947, extensive tests of the carrying capacity, operating characteristics and hydraulic properties of the aqueduct were made. The results of these tests were very satisfactory and indicated that the maximum carrying capacity of the line was more than 20 per cent above the normal design figure.

Loss in Capacity a Serious Matter

Because of the great need for water in the San Diego area, every effort was made to operate the feeder at its maximum capacity. Flow at a rate of approximately 104 c.f.s. was maintained continuously until the middle of June, 1948. On June 14th it was observed that the water level was unusually high in the outlet structure at the San Jacinto Regulating Reservoir. An inspection revealed that the water was backing up in the aqueduct and that the freeboard at each of the open structures along the line was noticeably reduced. Within a few days it was necessary to reduce the rate of flow to less than 96 c.f.s. in order to keep some of the vent structures from overflowing. It was suspected that biological growths within the pipe were responsible for the reduced carrying capacity, and microscopical examination of several samples of deposit removed from a number of points along the line confirmed this.

Chlorination Tried as Remedial Measure

Chlorination of the water entering the San Diego Aqueduct, in an attempt to remove and control bacterial growths and biological films, was started on July 7, at which time the flow in the line was about 94 c.f.s. Two 1-ton cylinders of chloride were connected by a pipe manifold from which chlorine gas was fed into the aqueduct through a 2-inch rubber hose weighted at the discharge end to keep it submerged. The point of application was just below the outlet gate from San Jacinto Reservoir. On the basis of earlier chlorine demand tests which had been run on natural Colorado River water, an initial dosage of 3.5 to 4 ppm of chlorine was applied in order to carry a free-chlorine residual of about 1.0 ppm to the last open structure on the District's portion of the feeder. This rate of chlorine application was continued for 6 days, after which it was reduced to about 2.5 ppm. By July 19 (12 days of chlorination) the reservoir discharge had been increased to 99 c.f.s. When a carrying capacity of 100 c.f.s. was attained eight days later (July 27), no further increases in flow were sought. The freeboard at the structures continued to increase, however, and by November 1 was back to normal for 104 c.f.s. flow.

Continuous Chlorination for Combined Chlorine Residual

On October 16 a chlorinator was installed at the reservoir outlet (Fig. 3) and the chlorine dosage was reduced to between 0.5 and 0.6 ppm. This dosage was selected as a result of chlorine demand tests which had shown that the maximum combined-chlorine residual could be obtained from this rate of chlorine application to the water in San Jacinto Reservoir at that time. The chlorinator was a Wallace & Tiernan solution feeder

with a rated capacity 1000 pounds of chlorine per day. An 8-inch diameter hole was cut through the top of the 72-inch I.D. concrete pipe about 20 feet downstream from the outlet gate from the reservoir, and a concrete chimney with a 12-inch I.D. opening was built over this hole to provide access to the surface. A 2½-inch steel pipe was installed in this chimney, terminating at a point about two feet above the invert of the aqueduct line. This structure is pictured in Fig. 4. The rubber hose carrying the discharge from the chlorinator was passed through the steel pipe, so that the chlorine solution might be applied as far below the surface of the water as practicable. No diffuser was used.

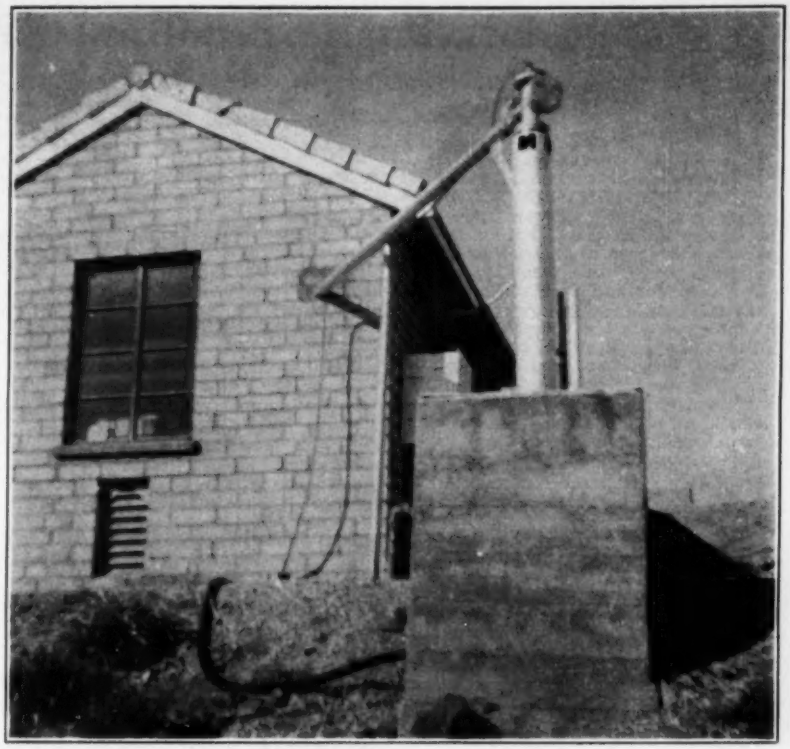


Fig. 4—CHLORINE inlet arrangement on aqueduct
Chlorine gas at regulated pressure is conveyed through ⅝" plastic hose which connects into 2" "Uscolite" pipe leading to chlorine inlet structure.

At intervals of one to three months, chlorine-demand curves were prepared from tests run on the reservoir water samples. On the basis of these data, the chlorine dosage was varied, as necessary, to maintain the maximum obtainable combined-chlorine residual. The chlorine dosage required to maintain this condition ranged from 0.5 to 1.1 ppm, depending upon the quantity of nitrogenous material present in the water—(Fig. 5). Occasionally, particularly in midsummer when water temperatures were at a maximum, the carrying capacity of the feeder would start to decrease slowly despite this continuous chlorination. Happily, application of chlorine at a dosage of about 3 to 4 ppm (Fig. 6) for 18 to 24 hours always restored the freeboard at the structures and the capacity of the line. For 10 months during the period from April 1951, to March 1952, a flow rate of more than 106 c.f.s. was maintained in the San Diego Feeder, a peak of 106.7 c.f.s. being attained. Comfortingly, this was fully 25 per cent more than the designed capacity of the line.

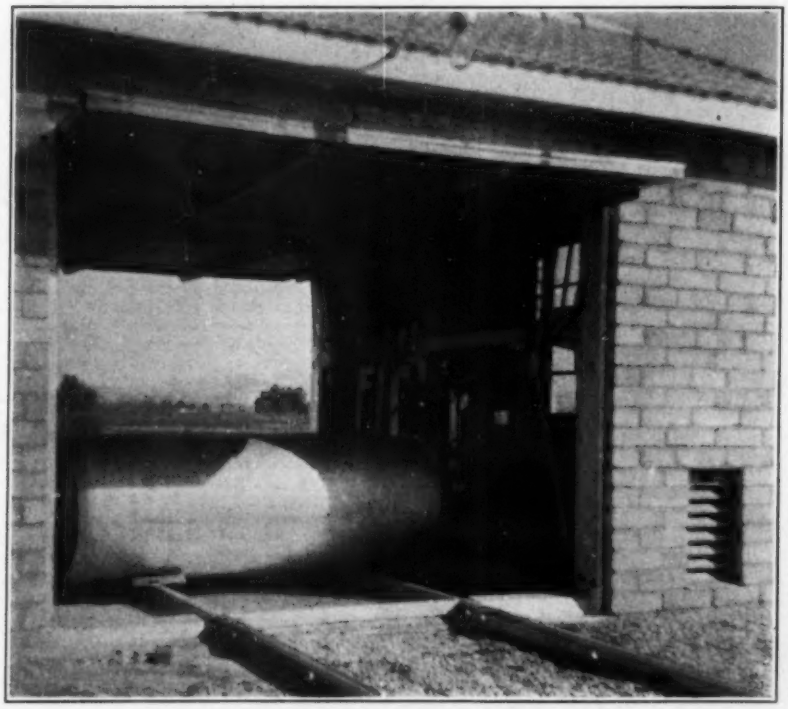


Fig. 3—CHLORINATING station at San Jacinto Reservoir
One-ton chlorine container on platform scale; W. & T. chlorinator in far corner on right.

Early in the summer of 1951 chlorination practice at San Jacinto Reservoir was modified to the extent that the higher dosage of chlorine (3 to 4 ppm) was applied at more frequent intervals but for only 2 to 6 hours during each period of application. Between these periods normal chlorination to the "hump" point on the breakpoint curve was still continued—(Fig. 5).

So successful did this procedure prove to be that it was decided to experiment with the use of intermittent high-dosage chlorination alone, without continuous low-dosage chlorination. While plans for this were in progress, the article by Jackson and Mayhan[10] appeared in *Water & Sewage Works*, describing the experience at Little Rock in maintaining supply line capacity by chlorination. This article confirmed the idea that contin-

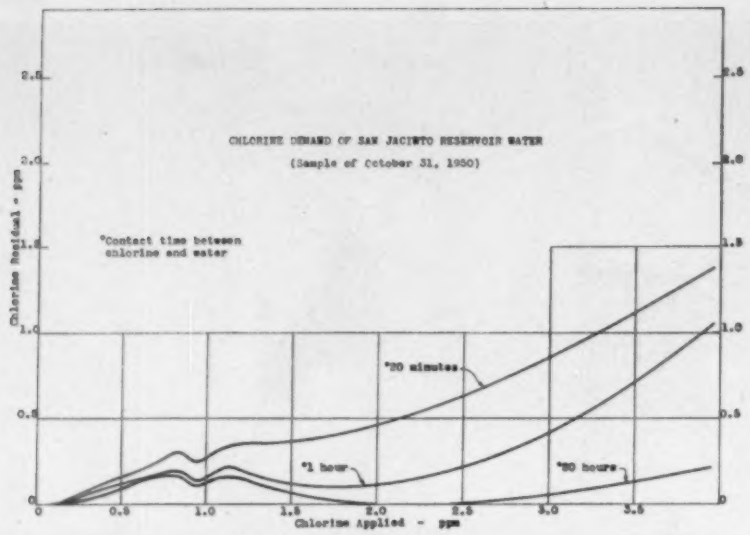

CHLORINE DEMAND OF SAN JACINTO RESERVOIR WATER
(Sample of October 31, 1950)
*Contact time between chlorine and water
*20 minutes
*1 hour
*20 hours
Chlorine Residual - ppm
Chlorine Applied - ppm

Fig. 5—CHLORINE DEMAND curves for San Jacinto Reservoir water Oct. 31, 1950

uous chlorination might not be necessary.

Intermittent Chlorination for Free Residual

Late in the fall of 1951 continuous chlorination at the San Diego Feeder was discontinued, and the program of chlorinating for 2 hours every day at a chlorine dosage of 2 to 3 ppm was instituted. When this schedule proved highly satisfactory, the frequency of chlorination was further reduced. At present, chlorine is applied twice each week, 100 pounds being used during each two-hour period of application. This is equivalent to a chlorine dosage of about 2.2 ppm for 2 hours at the current 100 c.f.s. rate of flow in the feeder. Aqueduct capacity is being very satisfactorily maintained, and freeboard at all the open structures is at a maximum. During the hottest summer months it may sometimes be necessary to increase the dosage temporarily—possibly to 150 pounds or even 200 pounds for 2 hours twice each week. Even at the latter dosage, however, the total chlorine used will add up to only 400 pounds per week. Compared with a usage of 300 to 600 pounds per day when continuous low-dosage chlorination was practiced, this represents a very substantial saving.

As the chlorinator formerly used for continuous low-dosage chlorination has a maximum capacity of about 960 pounds per day or 40 pounds per hour, it is not suitable for the present intermittent, higher-dosage chlorination. Instead, the chlorine gas drawn from the one-ton cylinders passes through a manifold into a pressure regulator. At reduced pressure it enters a 5/8" plastic garden hose which, in turn, is carried through a two-inch "Uscolite" pipe leading through the inlet structure into the aqueduct line. The plastic hose extends for a short distance along the invert of the 72" pipe, permitting the gas to bubble upward into the flowing water. Although a larger chlorinator, which would permit application of chlorine solution rather than chlorine gas, would simplify control of chlorine dosage and, perhaps, promote more efficient use of the chlorine applied, even the present equipment is effectively maintaining full capacity in the San Diego Aqueduct at very moderate cost and simplicity of operation.

Acknowledgments

The author wishes to acknowledge the cooperation received from T. J. Cain, Division Foreman, San Diego Aqueduct, and from the District's softening and filtration plant laboratory staff.

The Metropolitan Water District of Southern California is operated under the direction of Robert B. Diemer, General Manager and Chief Engineer.

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(3) Diemer, R. B. "Expansion of the Colorado River Aqueduct System," Jour. A.W.W.A. 45: 397-404 (1953)
(4) Jackson, L. A. and Mayhan, W. A. "Chlorination Maintains Supply Line Capacity," Water & Sewage Works 98: 248-252 (1951)

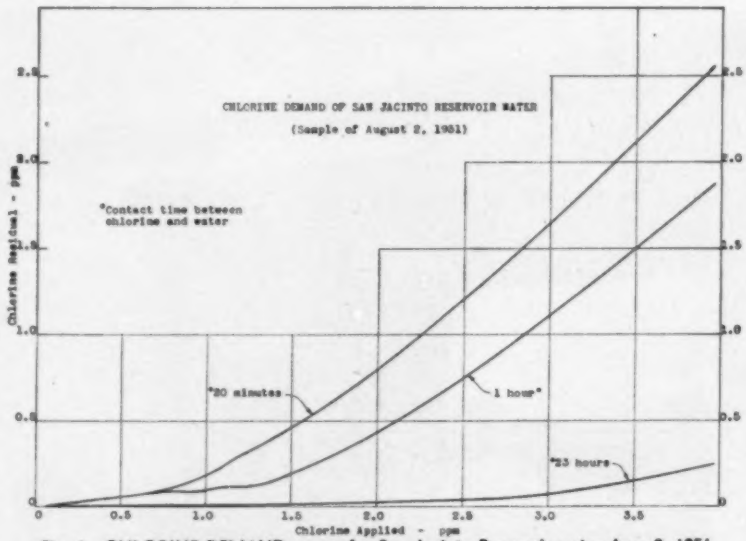
CHLORINE DEMAND OF SAN JACINTO RESERVOIR WATER
(Sample of August 2, 1951)
*Contact time between chlorine and water
*20 minutes
1 hour*
*23 hours
Chlorine Residual - ppm
Chlorine Applied - ppm

Fig. 6—CHLORINE DEMAND curves for San Jacinto Reservoir water Aug. 2, 1951

Financing Distribution System Extensions

By ALFRED O. NORRIS

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MANY methods and practices followed in the extension of distribution systems into new territory, many of which are not producing the income they should, require review and careful analysis to determine whether or not they are properly financed. It is quite conceivable that many extensions, although bringing in additional revenue, are, in fact, a financial burden on the system as a whole. Of course, some of the past methods cannot be changed overnight, as they are so securely fixed by custom, ordinance, or contract.

Equitable Rate Structure a Major Consideration

In considering this subject, there is one major factor to keep in mind—the rate structure or schedule. Almost every water works operator, whether his plant is publicly or privately owned, will find it most distasteful and difficult to revise the rate schedule of his property unless he is able to make the revision downward. It will be assumed, therefore, that it is the desire, and should be the responsibility, of every operator to approach the expansion of the water works system with an eye toward the preservation of the existing charges for water service. Precaution should also be taken to prevent the necessity of increasing the rates charged existing customers to help defray the costs of taking on new customers supplied by main extensions not properly financed.

Two factors must be considered in the proper financing of an extension: first, the revenue of the particular extension and the increase in operating expenses it will cause; and second, the additions to plant and property—such as services and meters—as well as the investment in pumps, filters, reservoirs and the like, that will be required to supply adequately the extension and the consumers taking water from it.

Calculating Probable Revenue

The calculation of the probable revenue from an extension can be approached from several angles. Rather than estimating the total revenue an extension may produce and working out the financing from this point, it is better and safer to eliminate as much guesswork as possible. There never is the certainty that all the lots will be built upon and, if built upon, that the units will be occupied. To reduce these uncertainties to a minimum, it is, therefore, best to work out the problem by giving consideration to the additional revenue as water customers become attached to the mains.

From the general character of the development and its location, as well as the size and design of the units, it is not too difficult to arrive at an average estimated revenue to be expected from each unit to be served by the extension. Such an estimate is, of course, based on the revenues being received from similar units already attached to the system.

The probable operating expenses of an extension—or rather the increase in the operating expenses of the property as a whole due to the addition of the new customers—cannot be properly approached by any method other than average costs. It would require an exhaustive study to find out by what increment each new customer would increase operating expenses, and if this increment were to be determined for each new customer it would naturally have to vary. Such an approach would also make it necessary to determine just which new customer required the hiring of an additional employee in the water works organization. As the development of this paper will show, the economies of an extension can be properly treated only on an overall basis and with a long-term view.

Average costs can best be expressed by giving consideration and weight to the operating ratio, the percentage of the gross operating earnings expended for operation and maintenance. Deducting this figure from the gross operating earnings gives the return—that is the amount available to meet the costs of borrowed capital and to provide a profit. Operating ratios are not the same for all properties as each has its own particular problem, affecting in one way or another the relationship between revenues and expenses. The operating ratio of a single property will, however, remain fairly constant from year to year, moving in one direction or the other rather slowly. To determine the operating ratio of a property for use in calculating the earnings of an extension, it would be well to figure it out for a number of years in order to eliminate any years during which some unusual event occurred and materially disturbed the operating ratio for that year.

Example

To take an example, it may be assumed that the estimated gross revenues from the extension under consideration average $15.00 a unit and that the operating ratio of the water works property which is making the extension is 40 per cent. The return from each unit, disregarding other matters, will, therefore, be $15.00 minus $6.00 (40 per cent of 15), which leaves $9.00. This $9.00 is the amount of money that will be available from each unit to support the investment in the pipelines, service lines, meters and other materials making up the extension as well as other additions to the plant as a whole.

Investment Required in Other Facilities

It is at this point that the greatest tendency exists for making errors and omissions in the proper financing of distribution system extensions. Small properties which have no prospects of further growth and at the same time have ample supply facilities can assume that a reasonable return on the investment in the extension alone is sufficient. Should it develop, however, that the property needed some expansion of its supply, the earnings of the property under existing rates would not be sufficient to support an investment in additional supply facilities, which, by their very nature, are not revenue producers. In determining the proper financing arrangement for distribution system extensions, consideration must also be given to the required investment in other plant facilities.

Admittedly, additional investments in plant facilities, other than pipelines, are not in the same category as the investments made in pipelines. Plant facilities are added in larger steps and at uneven rates. In a property's history there will be times when the supply facilities are more than adequate and times when they should be enlarged.

However, assuming that the development of plant facilities has been kept reasonably abreast of the growth of the distribution system, and records have been accurately maintained, the ratio of the total cost of, or investment in, pipelines alone to the total investment will provide a very useful figure in determining what the proper return on a pipeline extension should be. This ratio is arrived at by dividing the total cost or investment in pipelines, fire hydrants and fire hydrant branches by the total plant value. The figure should not vary much from year to year in the future, as it is based on total values over a long period and yearly variations will be small by comparison.

Apportioning the Investment

Assuming that the investment in pipelines alone of the water works property mentioned above is 45 per cent of the total value of the plant, for every $45 invested in pipelines another $55 will eventually have to be expended for all other facilities needed to render service to customers on the extension under consideration. Put in another way, this means that, at the particular imaginary plant, for every $1.00 invested in water mains, fire hydrants and hydrant branches $1.22 will have to be spent on other facilities.

It was found previously that of the $15.00 of estimated revenue for each unit, $6.00 would be spent on operating expenses, leaving $9.00 available to support the investment in the facilities needed to supply each unit. For the purposes of this paper, a return of 6 per cent on the value of the property will be assumed sufficient to cover the overall costs of borrowed money and a reasonable profit. The $9.00 using the figure of 6 per cent will therefore support an investment of $150. This $150, unfortunately, is not the amount of money that can be prudently spent on pipelines for each of the $15.00 customers expected on the extension under consideration. To take care of the cost of other facilities to supply each of these new customers, only 45 per cent of the $150, or $67.50, can be invested in water mains. The remainder, $82.50, will have to be spent on other facilities, such as meters, services, pumps and filters, if the existing relationship of the cost of mains to the total value of property holds true.

If the need for investment in all possible facilities other than mains is neglected when arriving at the return an extension should yield, it will become necessary to increase water rates at some future time. If all the revenue available from an extension is used to support the investment in pipelines alone, there will not be any cushion of revenue to support the investment in other needed facilities, such as added filter and pumping capacity. Furthermore, should it be found necessary to increase rates to support the cost of added facilities because of such omission, the increased rates would be imposed on the old customers for whom the additional facilities were not needed, as well as on the new customers.

Calculating Return Necessary

With an operating ratio of 40 per cent, a figure of 45 per cent representing the ratio of the value of pipelines to the total value

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of the plant and 6 per cent as a fair return, $15.00 of revenue could support an investment of $67.50 in pipelines. This represents a gross return of 22.2 per cent, calculated by dividing $67.50 into $15.00. The dollar figures can be eliminated and, using only the three percentages, the same 22.2 per cent can be arrived at thus:

$$\frac{0.06}{0.60 \times 0.45} = \frac{1}{4.5} = 0.222 = 22.2\%$$

The 22.2 per cent figure means that a water works property operating under the above conditions must earn 22.2 per cent of the cost of a pipeline extension to pay the increased operating expenses and receive a return of 6 per cent on the cost of the extension and the cost of other necessary additions to its supply facilities used in rendering service to the extension customers.

As mentioned before, probably no two water works properties have exactly the same operating ratio or relationship between the total value of pipe and the total value of plant. However, assuming that records have been kept so that it is possible to determine what these two percentage figures are, and that the desired return has been established, the same calculations as above can be made to determine what the gross yield on a pipeline extension should be, expressed as a percentage of the cost of the extension.

Assuring the Proper Return

When it is apparent that a pipeline extension will not yield the desired gross return on the cost of pipeline installation alone, it is quite essential that some arrangement be agreed on so that the water property will be assured of the proper return.

One way would be to work out with the developer, or a representative of the customers to be served by the extension, an agreement by which the water property would be guaranteed the required return (22 per cent in the example used). The water utility would then keep an account of the revenue collected on the extension each year and calculate what percentage of the cost of the extension this revenue represented. The guarantor would then make up the difference between the percentage found and the guaranteed amount, until such time as the actual annual revenue collected equalled or exceeded the required amount.

This type of contract does not have much appeal to a developer or an individual, because of its continuing nature. Furthermore, it would not be of much value to the utility unless the credit of the guarantor were well established. The most satisfactory arrangement from the utility's point of view, and also from the developer's, is to have the entire cost of the pipeline extension placed on deposit with the utility. The utility then has the money and the developer has some definite figure to work with for the determination of his costs of development.

Since the utility can calculate what its gross return on an extension should be, it ought to be willing to refund to the depositor sums of money which would be representative of the amount the utility can afford to invest for the revenue produced by the new customers added to the extension. Using the same gross return of 22.2 per cent and the estimated revenue of $15.00 previously assumed for each unit on the extension, the utility can afford to refund, for each unit added to the extension, a sum equivalent to $15.00 divided by the desired gross return of 22.2 per cent, or $67.50. This should be recognized as the same figure previously arrived at.

Expressed in another way, using the reciprocal of 0.222 which is 4.5, and multiplying: $4.5 \times \$15.00 = \$67.50$. This reciprocal can be used to express briefly what the utility can invest in pipeline extensions; namely, 4½ times the estimated revenue.

This factor of 4½ would not hold true for all properties, but a similar figure can be developed for any given utility.

PIPE FLOW CHART

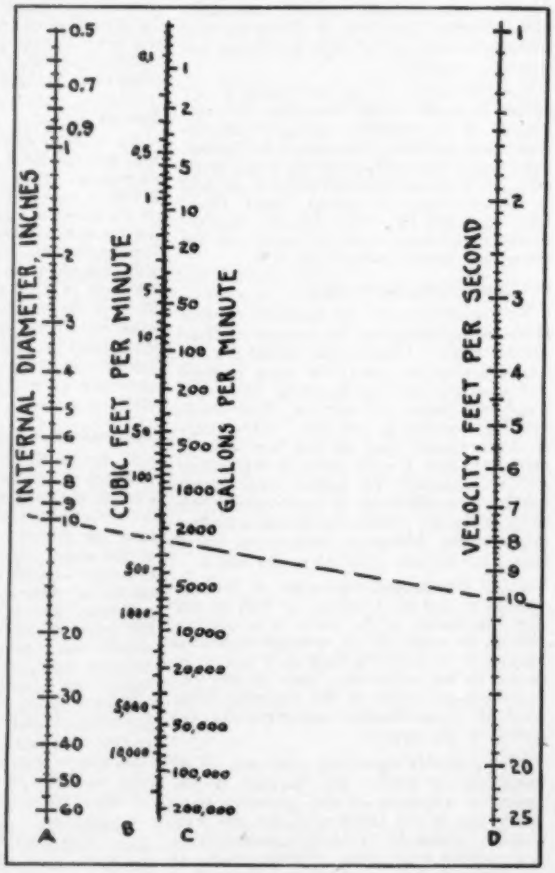
By simply laying a straightedge across this chart any one of these questions may be answered:

1. How many cubic feet will flow through a pipe of given diameter at a given velocity?
2. How many gallons, other conditions being the same as in No. 1.
3. What will be the velocity in feet per second, knowing the diameter and cubic feet per minute?
4. Same as (3) except that the flow is given in gallons per minute.
5. What diameter of pipe must be used to carry a given number of cubic feet per minute at a given velocity?
6. Same as (5) except that quantity is in gallons per minute.

For example, how many gallons of water per minute will flow from a 10 inch pipe line if the velocity reaches 10 ft. per second?

The dotted line drawn across the chart shows that if the internal diameter of the pipe is 10 inches (col. A), and the water is flowing at a velocity of 10 ft. per second (col. D), the amount of water flowing is a hair less than 2,500 gal. per minute (col. C), which is equivalent to about 325 cubic feet per minute (col. B).

Naturally the chart may be used to obtain the pipe diameter needed to avoid exceeding a given velocity at a given rate of flow. It may also be used for converting gallons to cubic feet and the reverse.



Contributed by W. F. Schaphorst, M.E., Newark, N. J.

Hydraulics of Single Pipe Lines

By D. R. TAYLOR

Genl. Mgr., Baton Rouge Water Works Co., Baton Rouge, La.

THERE are few public water supplies that are not occasionally confronted with the problem of augmenting existing distribution mains or feeder mains to serve suburban areas of doubtful future growth, or surprisingly successful subdivisions which have outgrown the capacity of present facilities.

The problem is usually one of lessening the friction loss to provide more residual pressure or of increasing the rate of flow, or both.

The purpose of this article is to present and explain a simplified solution of such problems by use of simple arithmetic. The method described provides a quick method for those who are experienced with the use of the Hazen and Williams formula and also for those who are unfamiliar with the use of logarithms, the log log slide rule or the hydraulic slide rule.

Tables have been prepared and one formula has been reduced to a form involving only squares and square roots, all to eliminate the necessity of calculations with fractional exponentials.

To solve such problems, it is necessary to know the actual diameter of the pipes involved, because nominal diameters, in some cases, do not indicate relative capacities and friction losses closely enough. For instance, some three-inch cast iron pipe is actually three and three-tenths inches in diameter with a friction loss of only sixty-three percent of that indicated by its nominal diameter. Nominal and actual diameters are shown in Table 1. The diameters used for all galvanized pipe are for standard weight steel pipe and those for cast iron pipe are for 150 pounds pressure SuperdeLavaud bell and spigot and mechanical joint pipe conforming with Federal Specifications WW-P-421, except in sizes 1⅞" to 2¼" inclusive, which are sizes formerly or presently manufactured by several foundries and by various methods, for 150 pounds pressure or more.

The actual diameter of SuperdeLavaud mechanical joint pipe is the same as that for bell and spigot pipe in sizes from 3" to 12" inclusive. However, the diameter differs for sizes larger than 12". Actual diameter for both types are shown for sizes 14" to 20" inclusive. The bell and spigot pipe is indicated by the letters "CI" and the mechanical joint pipe by the letters "CIM."

Relative capacities and friction losses of pipes, based on actual diameters, are shown in Table 2. The main portion of the table is for galvanized steel and bell and spigot cast iron pipe. Mechanical joint cast iron pipe (indicated as CIM) is included in the table as an insert.

The upper figure in each block in Table 2 is the comparative capacity or rate of flow expressed as a multiplier. The fractional figures beneath in the same block is the comparative friction loss expressed as per cent, as compared with the capacity and friction loss of any other size of pipe shown in the vertical columns at the extreme left and right.

For instance, the capacity of a 16" cast iron B & S pipe is 2.25 times or 225 per cent of that for a 12" cast iron B & S pipe when the friction loss is the same. The friction loss is only .224 times or 22.4 per cent of that for the 12" pipe for the same rate of flow. The corresponding values for 16" cast iron mechanical joint pipe as compared with 12" cast iron B & S pipe are 2.11 and .253 respectively (see insert Table 2).

Formulas:
When:
Q = gallons per minute
S = friction loss in pounds per square inch
D = diameter in inches
De = equivalent diameter in inches
Q_1 S_1 D_1 = values known or considered first
Q_2 S_2 D_2 = values unknown or considered second

$$Q_2 = Q_1 \left[\frac{S_2}{S_1}\right]^{0.54} \quad (1)$$

$$S_2 = S_1 \left[\frac{Q_2}{Q_1}\right]^{1.85} \quad (2)$$

$$S_2 = S_1 \left[\frac{D_1}{D_2}\right]^{4.87} \quad (3)$$

$$De = 0.92\sqrt{D_1^2 + D_2^2} \quad (4)$$

$$Q_2 = Q_1 \left[\frac{D_2}{D_1}\right]^{2.63} \quad (5)$$

If any type of pipe is involved, other than those shown in Table 2, the actual diameter should be determined and relative capacity and friction loss calculated by formulas (5) and (3) respectively.

The Design Process

Problem 1

Assume that a 4" cast iron main (of any length) serving one or more suburban sub-divisions has become inadequate and that it is decided to replace this main with a 6" cast iron main.

A. What increase in rate of flow may be expected with the same friction loss?

2.88 times or 288% (Table 2)

B. What friction loss may be expected with the same rate of flow?

.142 times or 14.2%

C. What rate of flow may be expected with only one-half of the former friction loss? Assume that the former friction loss was unity (1.0).

$$Q_2 = Q_1 \left[\frac{S_2}{S_1}\right]^{0.54} \quad \text{Formula (1)}$$

$$Q_2 = 2.88 \left[\frac{S_2}{S_1}\right]^{0.54}$$

$$= 2.88 \left[\frac{.5}{1}\right]^{0.54}$$

$$= 2.88\ (.5)^{0.54}$$

From Table 4, $(.5)^{0.54} = .687$

$Q_2 = 2.88 \times .687 = 1.98$ or an increase of 98%

D. What friction loss may be expected with only 50% more flow? Assume that the former flow was unity (1.0).

$$S_2 = S_1 \left[\frac{Q_2}{Q_1}\right]^{1.85}$$

$$S_2 = .142 \left[\frac{1.50}{1}\right]^{1.85}$$

$$= .142\ (1.50)^{1.85}$$

From Table 3, $(1.50)^{1.85} = 2.12$

$S_2 = .142 \times 2.12 = .301$ or only 30.1% of the former friction loss

Problem 2

Assume the same conditions as in problem 1 and assume that it is desired to replace only enough of the 4" main with 6" main to reduce the friction loss 25%.

Table 1
NOMINAL AND ACTUAL DIAMETERS OF PIPES IN INCHES

Nominal	Actual	Nominal	Actual	Nominal	Actual	Nominal	Actual
½ Galv	.622	2 Galv	2.067	4 CI	4.12	16 CIM	16.20
¾ Galv	.824	2½ CI	2.125	6 CI	6.16	16 CI	16.60
1 Galv	1.049	2¼ CI	2.25	8 CI	8.21	18 CIM	18.20
1¼ Galv	1.380	2½ Galv	2.469	10 CI	10.16	18 CI	18.62
1½ Galv	1.610	3 Galv	3.068	12 CI	12.20	20 CIM	20.24
1¾ CI	1.875	3 CI	3.30	14 CIM*	14.20	20 CI	20.70
2 CI	2.00	4 Galv	4.026	14 CI	14.55		

*CIM—Mechanical Joint Cast Iron Pipe.

TABLE 2
RELATIVE CAPACITY AND FRICTION LOSSES THROUGH PIPES
(Based on Actual Diameters)

	¾ Galv	1 Galv	1¼ Galv	1½ Galv	1¼ CI	2 CI	2 Galv	2½ CI	2½ CI	2½ Galv	3 Galv	3 CI	4 Galv	4 CI	6 CI	8 CI	10 CI	12 CI	14 CI	16 CI	18 CI	20 CI	
½ Galv	2.09 .25	3.95 .075	8.1 .021	12.2 .01	18.0 .005																		½ Galv
¾ Galv		1.89 .31	3.88 .08	5.84 .04	8.7 .018	10.3 .013	11.2 .011	12.1 .01															¾ Galv
1 Galv			2.06 .26	3.09 .124	4.62 .058	5.5 .043	6.0 .036	6.4 .032	7.48 .024	9.5 .016	16.7 .005												1 Galv
1¼ Galv				1.49 .47	2.25 .224	2.66 .163	2.88 .14	3.18 .128	3.62 .092	4.6 .058	8.2 .021	9.9 .014											1¼ Galv
1½ Galv					1.49 .47	1.76 .348	1.93 .29	2.07 .258	2.42 .195	3.09 .125	5.45 .044	6.6 .03	11.2 .011										1½ Galv
1¼ CI						1.18 .73	1.29 .62	1.38 .55	1.65 .394	2.05 .264	3.64 .09	4.42 .054	7.5 .024	7.9 .022									1¼ CI
2 CI							1.09 .83	1.17 .74	1.36 .563	1.74 .358	3.08 .125	3.74 .098	6.3 .033	6.7 .03	19.2 .001								2 CI
2 Galv								1.09 .86	1.25 .657	1.59 .42	2.83 .145	3.42 .10	5.76 .038	6.1 .034	17.7 .005								2 Galv
2½ CI									1.16 .753	1.48 .48	2.61 .17	3.18 .12	5.38 .044	5.71 .042	16.4 .005	35.0 .001							2½ CI
2½ CI										1.28 .635	2.26 .22	2.76 .153	4.63 .058	4.93 .052	14.2 .009	30.5 .002							2½ CI
2½ Galv											1.77 .347	2.15 .24	3.62 .093	3.85 .082	11.2 .012	23.6 .003							2½ Galv
3 Galv												1.21 .70	2.08 .26	2.17 .237	6.3 .033	13.2 .008	23.2 .003						3 Galv
3 CI													1.69 .38	1.79 .34	5.15 .048	11.0 .011	19.2 .004	31.2 .002					3 CI
4 Galv														1.06 .867	3.06 .126	6.5 .031	11.4 .011	18.4 .005	29.2 .002	41.2 .001			4 Galv
4 CI															2.88 .142	6.1 .035	10.8 .012	17.4 .005	27.5 .002	39.0 .001	49.6 .001		4 CI
6 CI																2.12 .246	3.72 0.87	6.0 .036	9.6 .015	13.5 .008	18.2 .005		6 CI
8 CI																	1.75 .355	2.84 .145	4.5 .062	5.98 .036	8.63 .018	11.4 .011	8 CI
10 CI																		1.62 .41	2.57 .172	3.42 .103	4.94 .053	6.5 .031	10 CI
12 CI																			1.38 .43	2.25 .224	3.04 .127	4.0 .076	12 CI
14 CI																				1.32 .598	1.91 .301	2.52 .18	14 CI
16 CI																					1.35 .570	1.91 .303	16 CI
18 CI																						1.32 .598	18 CI

MECHANICAL JOINT

	14 CIM	16 CIM	18 CIM	20 CIM
4 Galv	27.5 .002	38.8 .001		
4 CI	25.9 .002	37.0 .001	49.6 .001	
6 CI	9.06 .012	12.7 .003	17.2 .005	23.0 .003
8 CI	4.23 .07	5.95 .037	8.1 .021	10.8 .012
10 CI	2.42 .196	3.42 .103	4.62 .058	6.14 .035
12 CI	1.49 .48	2.11 .253	2.86 .143	3.8 .085
14 CIM		1.41 .523	1.92 .298	2.54 .178
16 CIM			1.36 .567	1.8 .337
18 CIM				1.35 5.73

A. What per cent of the length of the 4″ main should be replaced with 6″ main?

Assume that the present friction loss of the 4″ main is unity or 1.0. From table 2, the friction loss of the 6″ is .142.

1.0 − .142 = .858, which is the difference in friction loss in per cent, for any length.

.25 ÷ .858 = .292

Therefore, to reduce the friction loss of the 4″ main 25%, it will be necessary to replace 29.2% of its length with 6″ main.

B. What per cent of the 4″ main should be replaced with 6″ main to increase the rate of flow 25% (from 1.0 to 1.25) with the friction loss remaining the same?

To increase the flow to 1.25 it will be necessary to decrease the total friction loss to a sum, that can be designated as x, which when divided into 1.0 (the present friction loss) will equal $(1.25)^{1.85}$

From table 3 $(1.25)^{1.85} = 1.51$—see formulas (1) and (2).

Then, $1 \div x = 1.51$, and

$x = 1.0 \div 1.51 = .661 =$ desired total friction loss.

1.0 − .661 = .339 = necessary reduction in friction loss (33.9%).

1.0 − .142 = .858 (see problem 2A).

.339 ÷ .858 = .395 = 39.5% of 4″ main to be replaced with 6″ to increase the flow 25% with the same friction loss.

The proof of this calculation, which is also applicable to any similar problem, when proof is desired, is as follows:

If the friction loss of the present 4″ main is 1.00 and 39.5% is replaced with 6″ main, the friction

Table 3
1.85TH POWER OF NUMBERS
(1.10 to 5.0)

No.	1.10	1.20	1.25	1.30	1.40	1.50	1.60	1.70	1.75
Power	1.19	1.40	1.51	1.62	1.86	2.12	2.37	2.66	2.82

No.	1.80	1.90	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Power	2.97	3.28	3.6	5.45	7.62	10.15	13.0	16.2	19.6

Table 4
0.54TH POWER OF DECIMAL FRACTIONS
(.10 to 1.0)

No.	.10	.20	.25	.30	.40	.50	.60	.70	.75	.80	.90	1.0
Power	.288	.43	.473	.522	.61	.687	.758	.824	.856	.886	.945	1.0

loss of the remaining portion of the 4″ main will be .605 (1.0 — .395 = .605). The friction loss of the 39.5% of 6″ will be .0561 (.395 × .142 = .0561).

The total friction loss after the replacement will be,

for the 4″ — .6050
for the 6″ — .0561

Total — .6611
1.0 ÷ .6611 = 1.51

$Q_2=(1.51)^{0.54}=1.25$ or 125%. Formula 1

C. To reduce the friction loss 25% and also increase the flow of 25% requires the replacement of:

29.2% to reduce the friction loss and
39.5% to increase the flow

68.7% = total replacement.

Problem 3

Assume the same conditions as in problem 1, except that it is considered more expedient to parallel a portion of the 4″ main with 6″ main.

A. What per cent of the 4″ main should be paralleled with 6″ main to decrease the friction loss 25%? In this instance, it is necessary to determine the equivalent diameter of the 4″ and 6″ mains.

By formula 4, $De=0.92\sqrt{(4.12)^2+(6.16)^2}$
$=0.92\sqrt{54.91}$
$=6.817''$

Relative friction loss for 4″ and 6.817″ mains is by formula (3),

$$S_2=1\left[\frac{4.12}{6.817}\right]$$
$$=1\times(.604)^{4.87}$$

*From table 5, $(.60)^{4.87}=.084$
By interpolation (table 5), $(.604)^{4.87}=.0864$, say .086

Therefore, the friction loss of the equivalent main (6.817″) is 8.6% of that of the 4″ main.

To determine the per cent of 4″ main to be parallel with 6″ main to reduce the friction loss 25%, proceed as in problem 2A.

1.0—.086=.914
.25÷.914=.274=27.4% to be paralleled.

B. To determine what per cent should be paralled to increase the flow 25%, proceed as in problem 2B.

X=1÷1.51=.661
1.0—.661=.339
.339÷.914=.371=37.1% to be paralleled.

C. To reduce the friction loss 25% and also increase the flow 25% requires the paralleling of:

27.4% to reduce the friction loss and
37.1% to increase the flow

64.5% = total per cent paralleled.

Problem 4

A customer seeks advice. He can operate two lawn sprinklers at the rear of his property, from the end of his long line of ¾″ pipe, but he desires 50% more flow so that he can operate three sprinklers.

From table 2, a 1″ pipe will furnish 1.89 times or 89% more water, but only 50% more is desired. How much of the ¾″ pipe should be replaced with 1″?

From table 3 $(1.50)^{1.85}=2.12$.

X=1.0÷2.12=.472
1.0—.472=.528

From table 2, the friction loss for 1″ is .31 or 31% of that for ¾″.

1.0—.31=.69
.528÷.69=.765=76.5% of the ¾″ to be replaced with 1″ to increase the flow 50%.

Table 5
4.87TH POWER OF DECIMAL FRACTIONS
(.20 to .99)

	.80	.9	.82	.83	.84	.85	.86	.87	.88	.89
.2	.0004	.0005	.0006	.0008	.001	.0012	.0015	.0017	.002	.0025
.3	.0028	.0034	.004	.0045	.0053	.006	.007	.008	.009	.0103
.4	.0115	.013	.0148	.0165	.0182	.0206	.023	.0256	.028	.031
.5	.0343	.038	.0417	.046	.05	.055	.06	.065	.071	.077
.6	.084	.09	.0975	.106	.115	.1225	.1325	.1425	.154	.165
.7	.176	.188	.20	.216	.231	.247	.2635	.281	.30	.3175
.8	.338	.36	.381	.405	.429	.455	.48	.508	.5375	.5675
.9	.600	.6315	.666	.7025	.74	.7785	.82	.862	.9063	.9523

NUMBER OF TAPS THAT CAN BE TAKEN FROM PIPE OF VARIOUS SIZES

Diameter of Pipe in Inches	SIZE OF TAPS IN INCHES																						
	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
2	11	5	3	2	1																			
2½	20	9	5	3	1	1																		
3	32	15	8	5	2	1	1																	
3½	47	22	13	8	4	2	1	1																
4	65	32	18	11	5	3	2	1	1															
4½	88	42	24	15	7	4	2	1	1	1														
5	114	55	32	20	9	5	3	2	1	1	1													
6	181	88	50	32	15	8	5	3	2	2	1	1												
7	266	129	74	47	22	13	8	5	4	3	2	1	1											
8	371	181	103	65	32	18	11	7	5	4	3	2	1	1										
9		243	139	88	42	24	15	10	7	5	4	2	1	1	1									
10		316	181	114	55	32	20	13	9	7	5	3	2	1	1	1								
12			285	181	88	50	32	21	15	11	8	5	3	2	2	1	1							
14			419	266	129	74	47	32	22	17	13	8	5	4	3	2	1	1						
15				316	154	88	55	38	27	20	15	9	6	4	3	2	1	1	1					
16				371	181	103	65	44	32	23	18	11	7	5	4	3	2	1	1	1				
18					243	139	88	59	42	32	24	15	10	7	5	4	2	1	1	1	1			
20					316	181	114	78	55	41	32	20	13	9	7	5	3	2	2	1	1	1		
22						229	145	99	70	52	40	25	17	12	9	7	4	3	2	2	1	1	1	
24						285	181	123	88	65	50	32	21	15	11	8	5	3	3	2	2	1	1	1

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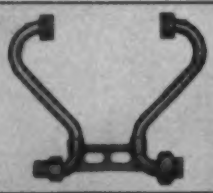

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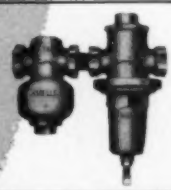

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The Measurement of Hydrant Discharge

By P. S. WILSON

Water Works Consultant, Glen Ridge, N. J.

THE measurements of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can debate for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.

Methods of Measuring Discharge

Measurement of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter

Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.

Determining Stream Velocity

The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage Indicating Barrel Pressure Show Practically Same Readings)

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stram and pointing dirctly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center of the stream will approximate the average pressure. In no case should the pressure very near the edge (within about one-fourth inch) be considered.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the

Hydrant Pitot Tube with Gage

stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadavantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained a diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14xd^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545xd^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream is feet per second =

$$\sqrt{2.31 \times p} \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =

$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =

$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =

$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =

$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

Tables and Charts

From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1.

TABLE 1

Hydrant Discharge*

Gallons per minute = 27 d^2 $\sqrt{p}$

Gage Reading—Hydrant nozzle diameter in inches [d]

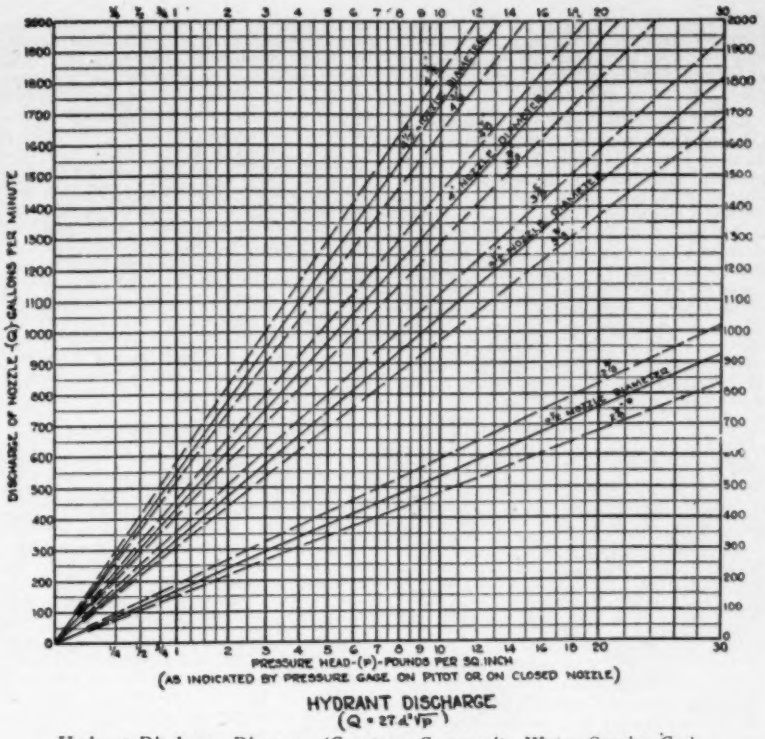
p	2 4/16	2 3/8	2 7/16	2 1/2	2 9/16	2 5/8
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	220	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	460
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	980
30	790	830	880	920	970	1020

*Discharges shown to nearest 10 gals. per min.

The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (d). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of d,— for example 2½ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing ⅛-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary.

Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.


DISCHARGE OF NOZZLE (Q) GALLONS PER MINUTE
PRESSURE HEAD-(P)-POUNDS PER SQ. INCH
(AS INDICATED BY PRESSURE GAGE ON PITOT OR ON CLOSED NOZZLE)
HYDRANT DISCHARGE
(Q = 27.4d²√p)

Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.)

Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this is will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the dis-

charge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 32.80 \text{ gal. per min.}$$

which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1 is the measured discharge with a drop in pressure of D_1; and Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

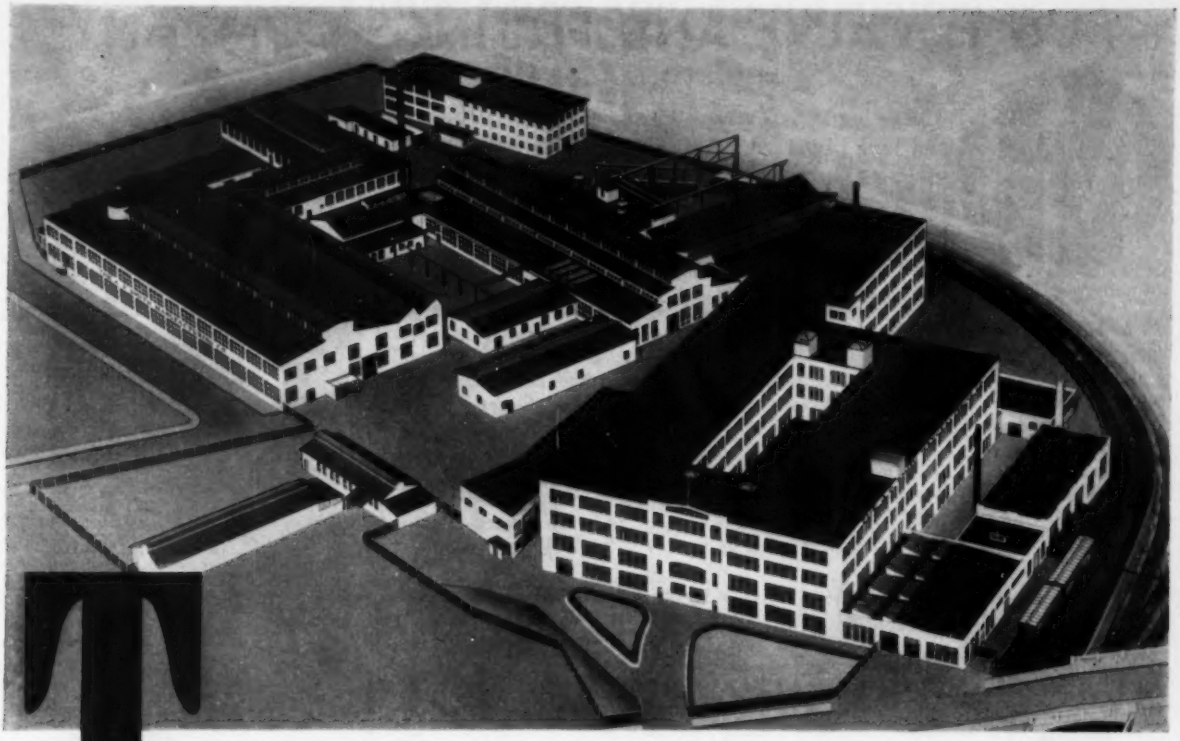
In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

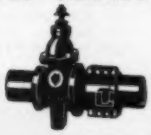
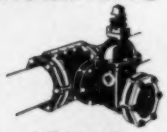
It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Degree of Hardness and Soap Consumption

Grains ($CaCO_3$) per U.S. Gallon	Parts per Million	Pure Soap Consumption (Lbs. per 1000 gals.)	Grains ($CaCO_3$) per U.S. Gallon	Parts per Million	Pure Soap Consumption (Lbs. per 1000 gals.)
1	17.1	1.3	21	359.1	28.4
2	34.2	2.7	22	376.2	29.7
3	51.3	4.0	23	393.3	31.0
4	68.4	5.4	24	410.4	32.3
5	85.5	6.7	25	427.5	33.7
6	102.6	8.1	26	444.6	35.0
7	119.7	9.5	27	461.7	36.3
8	136.8	10.8	28	478.8	37.7
9	153.9	12.1	29	495.9	39.0
10	171.0	13.5	30	513.0	40.5
11	188.1	14.8	31	530.1	41.8
12	205.2	16.2	32	547.2	43.2
13	222.3	17.5	33	564.3	44.4
14	239.4	18.9	34	581.4	45.7
15	256.5	20.2	35	598.5	47.1
16	273.6	21.6	36	615.6	48.5
17	290.7	22.9	37	632.7	49.8
18	307.8	24.3	38	649.8	51.2
19	324.9	25.6	39	666.9	52.5
20	342.0	27.0	40	684.0	53.8



THE A. P. SMITH MANUFACTURING CO.

produces, **FIRE HYDRANTS A. W. W. A. Specification and High Pressure — Compression Type — Dry and Wet Barrel Types.** **GATE VALVES sizes 2" thru 66", Manual, Hydraulic Cylinder, Electric Motor Operated for Low, Medium and High Pressure Service.**  **INSERTING VALVES sizes 4" thru 48" for inserting under pressure.**  **TAPPING SLEEVE AND VALVES sizes 4" x 2" thru 60" x 48" for branch connections under pressure.**

FIRE HYDRANTS · VALVES · SINCE 1896

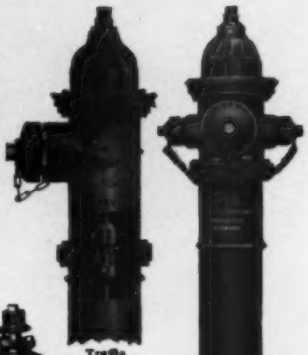
THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

The letters M & H are the sign of quality on Valves, Hydrants and Pipe Line accessories. High quality materials, simplicity of design and expert workmanship have established for M & H enviable reputation for dependable service in the water works and sewage fields and for industrial uses. M & H products are modern in design, with many exclusive M & H features.



Traffic Model Hydrant

Right: Standard Model Hydrant

Gate Valve

M & H VALVES AND FIRE HYDRANTS

M & H A.W.W.A. Gate Valves are furnished double disc, parallel seat, iron body, bronze mounted, non-rising stem, or outside screw and yoke. Available spur or bevel geared and with enclosed grease case, also hydraulically or electrically operated. Sizes 2" to 36". Low Pressure Valves and Square Bottom Valves are an established part of the M & H line.

M & H Compression Type Hydrants conform to latest specifications of the American Water Works Association. They are available either in standard or traffic models. Hydrants with 5¼" and 6¼" valve opening are listed and approved by Underwriters Laboratories of Chicago and Associated Factory Mutuals of Boston and A.W.W.A. Hydrants with 4¼" and 4½" valve opening are A.W.W.A. approved only.

Outstanding features include dry top, easy to lubricate, revolving head. Can be lengthened and working parts completely removed without digging up hydrant.

FILTER PLANTS & SEWAGE PLANTS

Hydraulically and electrically operated M & H Valves are used in sewage treatment plants, water works, filter plants, etc., to save time and labor since these valves can be operated by remote control for quick, easy closing or opening. They are also used as emergency valves to admit higher water pressures into the mains in case of fire. Sizes 2" to 36" A.W.W.A.

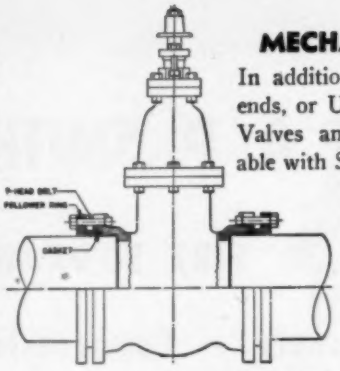
Hydraulic Gate Valve

Low Pressure Gate Valve Rising Stem

M & H Flap Valves and Shear Gates are iron body, bronze mounted, used in Filtration and Sewage Disposal Plants.

Low Pressure Gate Valve Non-Rising Stem

Shear Gate



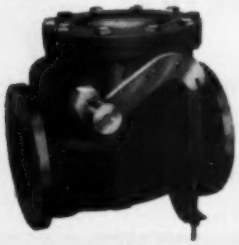
MECHANICAL JOINTS

In addition to hub ends, flanged ends, or Universal joints, M & H Valves and Hydrants are available with Standardized Mechanical Joint ends for use with standardized mechanical joint cast iron pipe.

FIRE PROTECTION

M & H makes a complete line of valves, hydrants, indicator posts and underground pipe fittings for fire protection water systems. All of these M & H products are approved and listed by the National Board of Fire Underwriters of Chicago and by the Associated Factory Mutuals of Boston. All castings therefore are marked "UA—FM."

Rising Stem Gate Valve



Spring Check Valve

Indicator Post

M & H PRODUCTS INCLUDE:

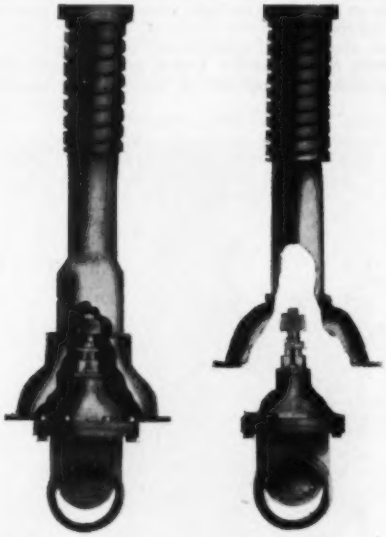
WALL CASTINGS	FLANGED FITTINGS	TAPPING SLEEVES AND VALVES
CHECK VALVES	FLOOR STANDS	SPRING LEVER CHECK VALVES
EXTENSION STEMS	SHEAR GATES	MUD VALVES
FLAP VALVES	B & S FITTINGS	FLANGE AND FLARE FITTINGS
	CUTTING-IN TEES	

Gate Valve Care and Maintenance

By ROGER W. ESTY
Superintendent, Water and Sewer Board, Danvers, Mass.

TOO commonly, one of the most neglected of the routine operations in a water works system is the care and maintenance of gate valves. In some of the larger cities there are maintenance crews created particularly for this type of work. The crew is generally made up of some of the older men who are experienced in this work, due to their long service with the department or the water company.

They are furnished with a truck equipped with all the necessary tools, wrenches and spare parts, and they may also have built into the truck a mechanical operating device to open and close the gate valves. Smaller towns are more often than not unable to give proper attention to their gates, due primarily to lack of sufficient man-power to do this work and carry on the many other essential activities common to a water works plant.



Valve Box Settings

On the left is a setting as it is pictured in catalogs, and generally installed. To my way of thinking, the method of putting the valve nut-up in the contracted section is improper. On the right is a suggested better way for the several reasons cited in the text. Possibly this may suggest an advantage to be gained in an improved design of this type of box to give better overall service.

My water works experience goes back over a period of 27 years. During that time I have located, measured and plotted onto cards and maps every hydrant, gate valve, and all of the pipe in our system. I have opened and closed every gate valve many times. It was 20 years ago that we first had a water waste survey made of our system and, as many know, this necessitates the opening and closing of essentially every gate valve in the system This type of work we have continued every second year since, which affords added opportunities of locating and operating all of our gate valves.

Main Flushing Reveals Gate Valve Conditions

Occasionally our piping system is entirely flushed out, street by street, and this again means the operating of nearly every gate valve, and some have to be opened and closed several times during this flushing operation if properly conducted.

From this work experience is gained in the knowledge of what to expect of gate valves and the remedies that are used in perfecting their operation.

Stiff Operation a Main Trouble

One of the main difficulties, if not the main difficulty, we find with gate valves is that they turn hard. As years go on, if such valves are not operated occasionally they become more difficult to operate and in some cities and towns it takes two men, or even as many as four and six men, to close down a gate valve even during a testing period.

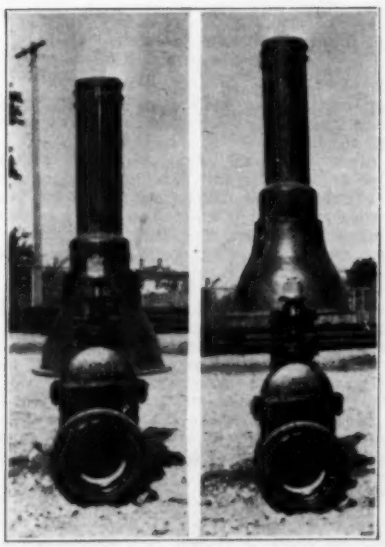
My experience does not go beyond a 20-inch gate valve, but it seems to me that the same principles and characteristics are applicable to all sizes.

A great deal of the indifference toward gate maintenance can be traced to the swivel chair operator. By that I mean the man in charge of the water works who has never experienced the opening and closing of all of the gate valves in his system. If he made tests of his system, such as a water waste survey, and had to work all night opening and closing these gate valves himself, he would soon issue an order to do something about making them operate easier. But generally, it is below his dignity to leave his swivel chair to do this type of work, to find out first hand the physical condition of his system. He doesn't care; he doesn't have to operate them; let the men do it, even if it does take two, four or six to do the job.

The Remedy

What are the difficulties we encounter; what causes them, and how can they be remedied? Why should it take four men to close a gate valve when one man should do it?

Why do stems get bent and broken? What is the cause of all this? Is it because the mechanism is not correct in design, or that the mechanism is not made heavy enough? I feel that the manufacturers as a general rule put on the market a gate valve that will meet all reasonable conditions according to our water works standard specifications. However, I do think the manufacturers do lose sight of one very important factor, and that factor is the packing, and in my opinion, if improper or



A photographic attempt to indicate the advantage of setting the box bonnet higher, giving more clearance between box walls and nut and stem of the valve. The usual setting (left) is in truth a "rock trap," while the other permits rocks to pass by; also makes for easier key connection with the nut should the box become off-center.

neglected packing is not the direct cause, it is at least the seat of 90 per cent of all gate valve troubles.

Many ask, why does the packing have such an important bearing on the ease of operation of the gate valve? Well, the packing gets dry and hard as the years go on. This dry packing acts as a brake on the valve stem.

Take, for instance, your automobile—the brake linings are dry and the brake drum of the wheel is smooth and dry. When the pressure is exerted against one another it creates friction, and

Danvers' Alemite Lubricating Outfit Servicing a Geared Valve.

this friction creates your braking or stopping power. Sometimes at high speeds this friction actually locks the wheels and causes fatal accidents.

On the other hand, pack the brake drums with grease and then attempt to stop your car. The grease eliminates the friction, therefore there is no friction created to stop your car.

Take a rope and wind it around an inch pipe three or four times and draw it tight and then attempt to turn the pipe. You will find you can't do it. Then grease the rope thoroughly and you will find that you can turn the pipe very easily. Try it for your own satisfaction.

Did you ever try holding an eel in your hand? If you have, you probably found that it was nearly impossible to hold it because it was so slippery. If you can get your gate valve stem and packing in the slippery condition you find the eel, you'll have no more hard turning gate valves.

However, there is a difference in the mechanism in some of the gate valves and one make may operate a little different than another make when new. But on the whole, modern gate valves should operate more or less in the same easy manner.

A Case of Proof

Several years ago, while making a water waste survey during nights, we came across a 12-inch gate most difficult to operate. It took the combined efforts of two of us to open and close the gate. The next day I had the gate dug up and repacked. It seems hardly believable, but it could then be turned with just one finger against the cross-bar of the gate key.

Such ease of operation surely saves breaking or bending the valve stems and makes the operation of the gate a pleasure instead of a dreaded job.

Some Packing Pointers

On many of our gate valves and nearly all of our hydrants we have removed the original braided packing and inserted a metallic plastic packing, with two or three strands of flax string type packing on top to keep it from squeezing out when the packing gland is tightened down.

After taking out all of the braided packing, we squirt down around the stem near the packing plate some kerosene or light lubricating oil. We then fill up the stuffing box with a metallic packing that comes in a loose plastic form or in string form. We then put on the stuffing box follower and tighten it down. We then open and close the valve a few turns and then tighten it some more. If it needs a little more packing we insert some and go through the operation again. This method has solved our packing problems and made hard turning gate valves easy turning, and makes fun out of a disagreeable job.

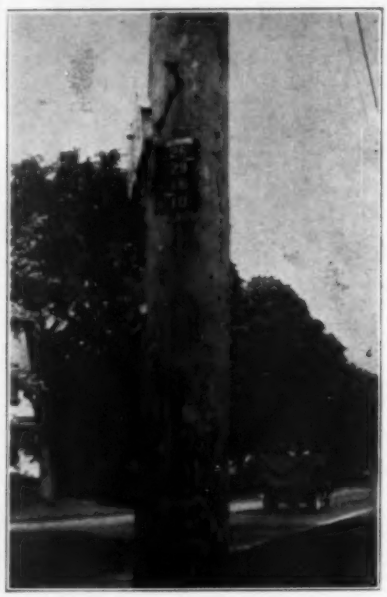
The Larger Valves

In the large gates we drill a hole through the packing plate and insert an alemite fitting. These gate valves still have the braided packing in the packing box. By connecting a grease gun to this fitting we can apply by means of our air compressor about 3,500 pounds pressure and this forces the grease in and around the stem and packing and does a very satisfactory job of lubricating.

It does such a good job on these gate valves that it is a monotonous one man job of opening and closing the valve when testing; in fact, a boy 10 years old can operate the valve.

Large gate valves should have an ample size manhole constructed around them so that a man can get down to the gate and repack it. Smaller gates can be handled more economically by using a 5¼ or 7-inch valve box over the gate with the cover flush with the road.

The gears of a geared gate should be enclosed in a housing with the gears running in oil. If the gears are not housed then they will collect rust and dirt in between the gears or teeth,



Danvers' Method of Marking Street Gate Locations.
Yellow figures stenciled on black field on nearest pole.

making them fit tight and bind, causing the gate to operate hard. Dirt falling down into the hole when the cover is picked up causes some of this trouble.

We have eleven 20-inch open geared gates and we wish we had purchased the oil enclosed style. That surely was an error on our part, but our experience with them has taught us to advise others to buy the oil enclosed style.

We have constructed a shield that fits over the gears and the operating nut and fastens to the bolts holding the stuffing box to the bonnet of the gate. This has proved very satisfactory and the dirt does not get into the gears. This gives us the opportunity to keep them well greased.

Improper Valve Box Setting

Many gate valve catalogues show what, in my opinion and experience, is an improper method of setting the box over the gate. Pick up any catalogue and turn to the gate box section

showing the 5¼ or 7-inch box. You will notice that the base or pot sets down over the top of the gate so that the base of the box is even with the flange in the center of the gate. Then the upper section, or middle section, is set onto the base, leaving the operating nut up in this section.

My contention of it being an improper setting and causing maintenance troubles is that if rocks do get into the boxes (and the kids sure do put them in sometimes), that the rock cannot go down past the operating nut. It gets wedged in so hard sometimes that it is impossible to get the key onto the operating nut, and if you do, you cannot turn it. If the box is pushed to one side slightly, the box then comes up against the operating nut and prevents putting the gate key onto the operating nut.

If, on the other hand, the base or pot is set so that the base is up at the level of the stuffing box plate, rocks then can roll to one side into the base, and if the box is tipped there is a greater possibility of getting the gate key onto the operating nut.

In my opinion, box setting is a very important part of your gate maintenance work.

Location Records

Location plans of gate valves should be carefully prepared and measurements should be taken from permanent benches, such as to other gate valves, hydrants, catch basin grates, manhole covers, curbs, etc., and not from telephone poles, trees, walls, fences, etc.

These measurements should be on cards and on sheets in bound books for quick reference. Each should have a number and these can be painted on the underneath side of the valve box cover if desired.

Stencilling of measurements onto buildings, poles, etc., are helpful for quick locating. Numbers can be nailed onto poles or buildings that will stay on as long as the pole or building remains in place. We paint a black square on the reference object and nail on the metal numbers that have been sprayed with an orange colored paint. The contrast makes it conspicuous from any other type of marking.

Removing Recalcitrant Box Covers

Sometimes the gate box cover gets sealed in with tar, or in the winter is frozen in. This can be very easily overcome by pouring a little gasoline on it and setting it on fire. In a few moments the cover can be easily removed.

Quite often it is found difficult to close the gate tightly. This is generally caused by tuberculation in the valve guides and seat. By opening and closing several times this incrustation breaks off and the velocity of the water between the gate and the seat of the valve will most always flush out, allowing the gates to eventually properly seat and closing off entirely the flow of water.

Gate valve work is not expensive. It is a tedious job but can be made very interesting by the various things that have to be done, such as checking measurements, marking poles or buildings, opening and closing, repacking, and the resetting of the gate box at higher elevation.

If a few of these suggestions are followed, most of your gate valve worries will be a thing of the past:

Good plans and measurements.

Stencilled or metallic reference numbers on poles, buildings, etc.

Gate box covers flush with the surface of the ground.

The base of the box well above the center flange of the valve.

Opening and closing each valve on a yearly schedule.

Last, and the most important, proper packing and lubrication.

And a good motto is:

"More turning of gate stems and less of swivel chair stems."

"Know your gate valves!"

Block and Tackle Chart

Here is a chart that will be found useful for determining safe loads and proper loads in connection with ordinary block and tackle.

By laying a straight edge across the chart, as indicated by the dotted line, the pull necessary to lift any weight up to 200,000 pounds is immediately given in column B.

This chart takes into account the friction of the ropes and pulleys, which is less for a smaller number of ropes, although the pull on the lead line is decreased if a larger number of ropes are employed.

For example, what pull on the lead line is required to lift 20,000 pounds with five ropes?

Solution: The graduation corresponding to 5 in column A is connected by a straight line with that corresponding to 20,000 pounds in column C. The straight line intersects column B at approximately 4,700, which is the pull required.

The number of ropes supporting the load and used in column A is determined by counting the ropes leading to and from the moving block as illustrated by the sketches.

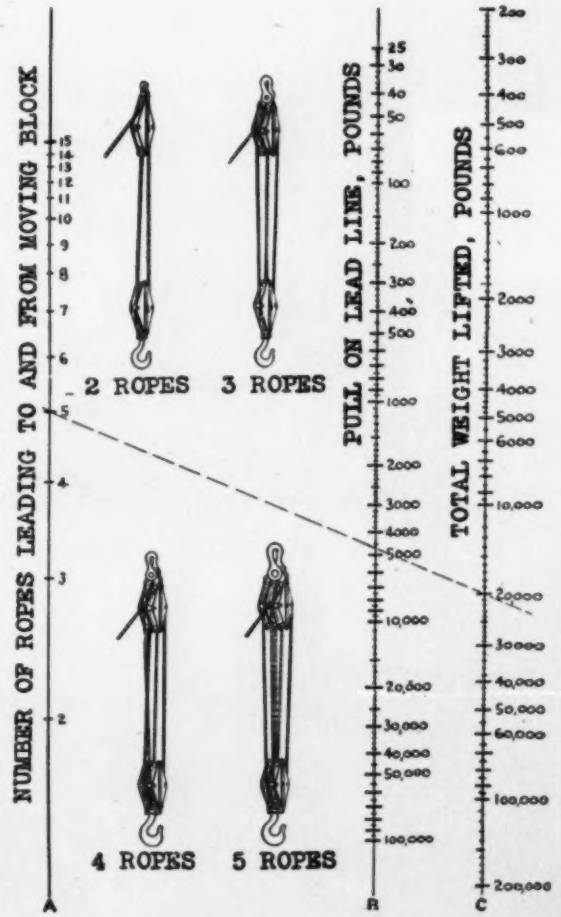
In arriving at the stress in the lead line, the common practice is to divide the weight of the load by the number of ropes supporting it, but this is not correct as it does not take into account the friction of the blocks or the rigidity and internal friction of the rope. The maximum stress when hoisting occurs in the lead line, since this besides taking a proportion of load on a single supporting rope also takes the accumulated friction of the blocks and rope in all the other parts of the tackle.

If, for example, a "seven rope" hoist is employed for raising a load of 35,000 pounds, according to the usual practice the stress in the lead line would be computed as 5,000 pounds, assuming that all parts pulled equally. This stress occurs, however, only in the becket line. The maximum stress is 6,325 pounds as determined by test. The chart gives that figure very closely, as will be observed.

Although this chart is based on figures that were determined for wire rope tackle, it is also applicable to ordinary manila rope.

It must be remembered, when buying a rope for use in a block and tackle, that the rope must be strong enough to resist the "maximum" pull, which is the pull in the *lead* line.

Contributed by W. F. Schaphorst, M. E., Newark, N. J.



BETHLEHEM

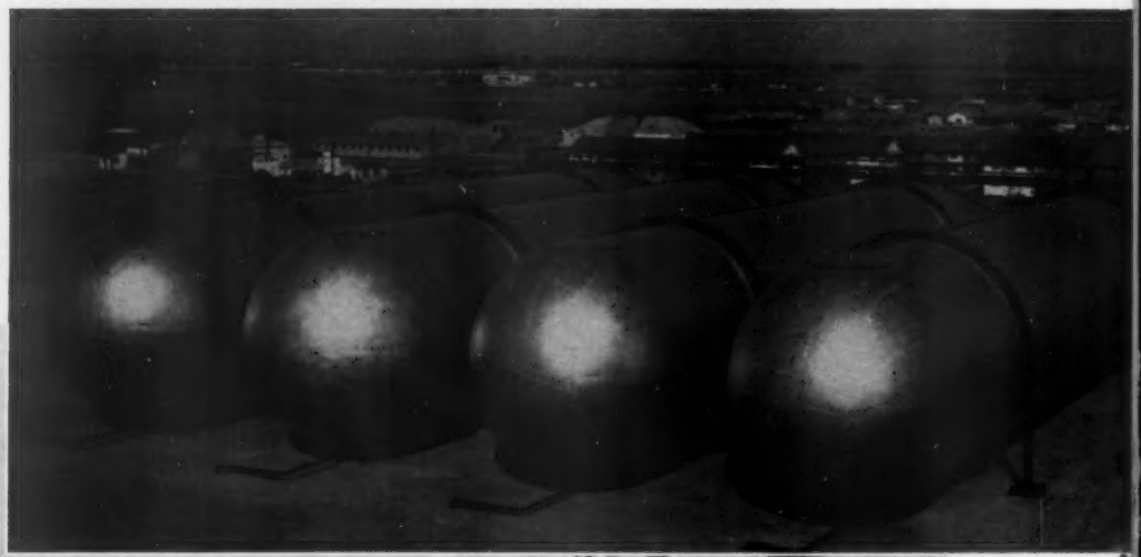
FOR WATER AND SEWAGE PIPE
WATER STORAGE TANKS AND STANDPIPES
GAS HOLDERS
PROPANE TANKS
GASOLINE AND OIL STORAGE TANKS

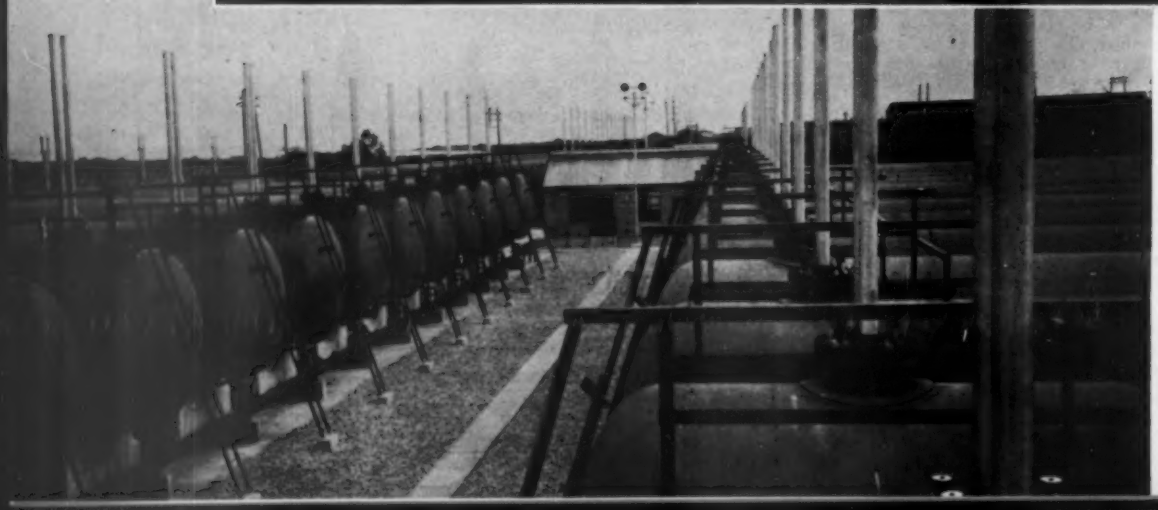
Bethlehem specializes in the design, fabrication and erection of tanks and holders for the storage of water, gas and oil, all furnished to AWWA or API specifications. The types shown here are a few examples of the thousands of Bethlehem-built tanks and holders giving satisfactory service in all parts of the country.

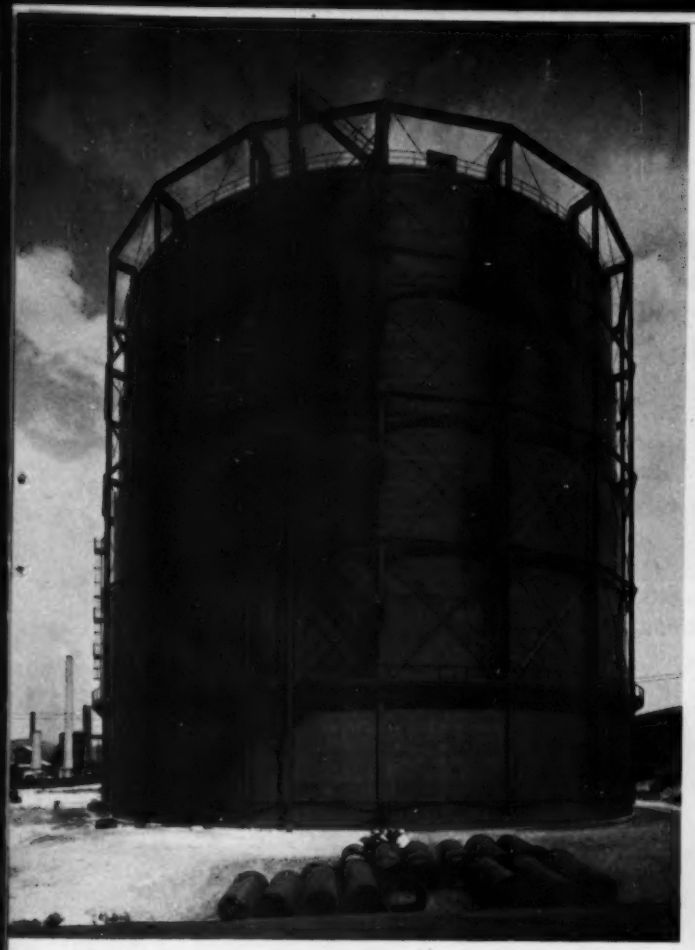
For full details, write or phone the Bethlehem sales office nearest you.

WELDED HIGH-PRESSURE horizontal gas holders, designed, fabricated and erected by Bethlehem. Each is 205 ft long, 34 ft in diameter. Total storage capacity of installation 500,000 cu ft.

At Bottom: **HIGH-PRESSURE** welded Bethlehem tanks at LP-Gas Terminal in Mobile, Ala.

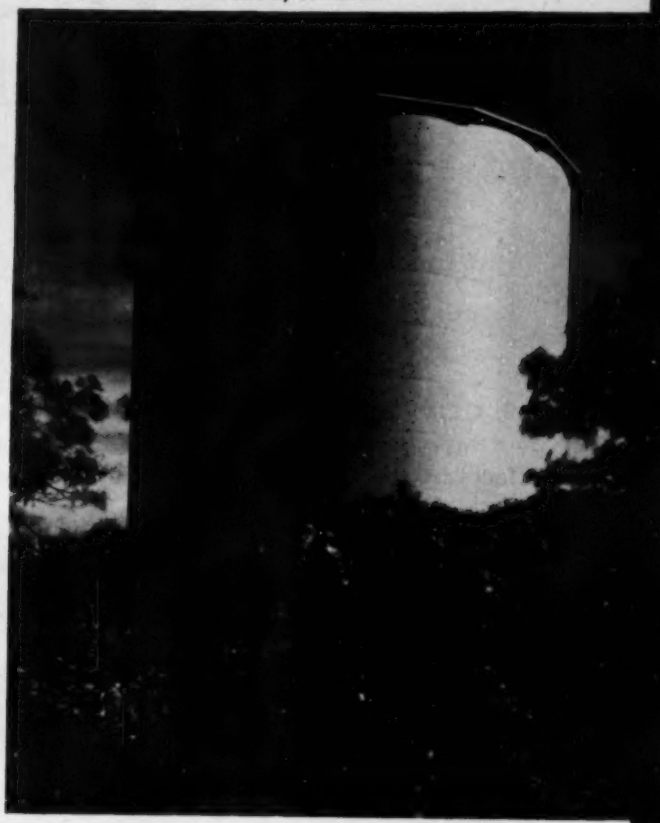


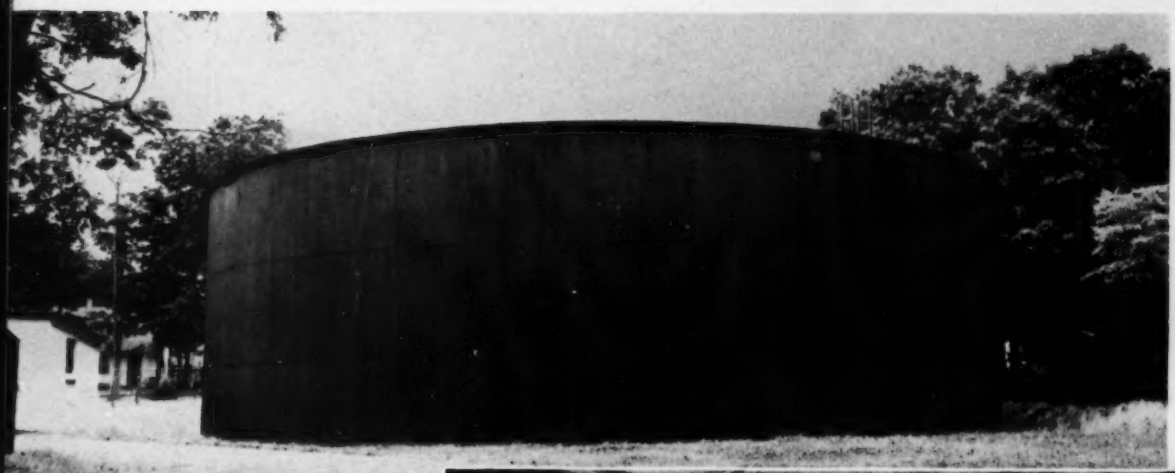




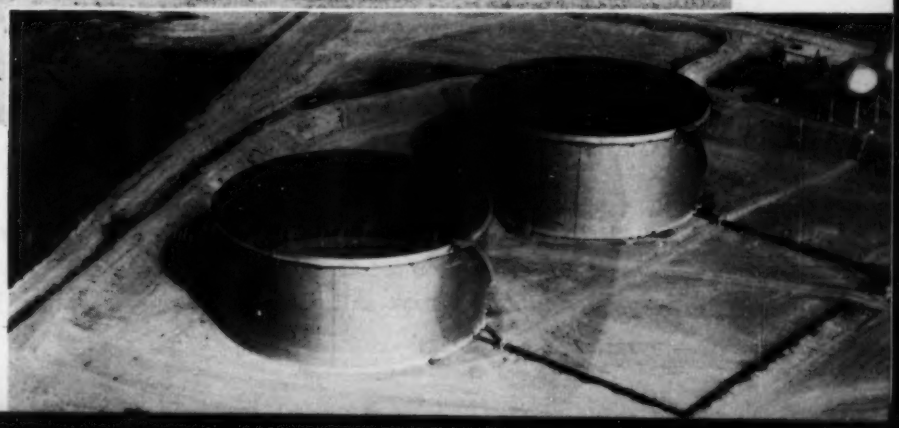
3,000,000-CU-FT vertical water-sealed gas holder, erected by Bethlehem in Hellertown, Pa.

2,000,000-GAL. STANDPIPE in Arlington, Mass., designed, fabricated and erected by Bethlehem.





ALL-WELDED WATER RESERVOIR on Long Island. This Bethlehem-built tank, 1,000,000 gal. in capacity, is 85 ft in diameter and 25 ft high.



TWO NEW Bethlehem double-deck lifter-roof oil storage tanks near Buffalo, N. Y. Capacity, 95,000 bbl. each.

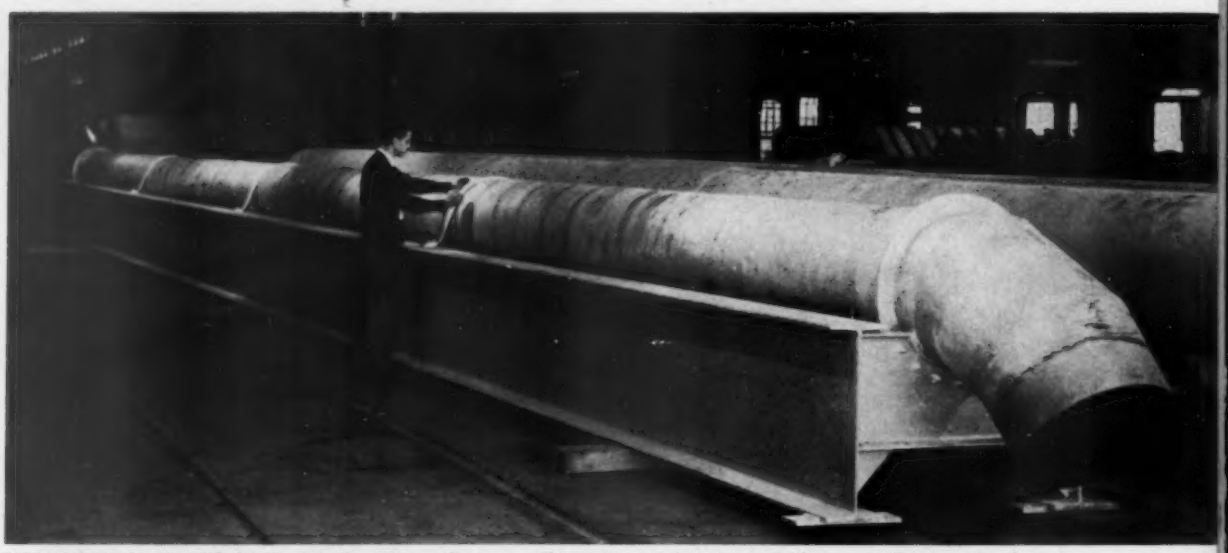
BETHLEHEM
TAR-ENAMELED STEEL PIPE
FOR WATER DISTRIBUTION AND SEWAGE DISPOSAL

Here are six good reasons for using economical, dependable Bethlehem Tar-Enameled Steel Pipe:

1. BEAM STRENGTH—It is made from high-quality steel plate. It's husky pipe, with high beam-strength. It can be handled in multiple lengths, and is unaffected by most washouts.

2. CORROSION-RESISTANCE—Bethlehem Steel Pipe is lined and coated with a smooth layer of coal-tar enamel, meeting AWWA Specifications. The enamel is impervious to corrosion and incrustration and ensures high flow-coefficients.

3. SHOCK-RESISTANCE—Bethlehem Steel Pipe is designed with a safety factor of about 4 against bursting. It is resistant to water-hammer, and can carry a load of nearly four times the working pressure.

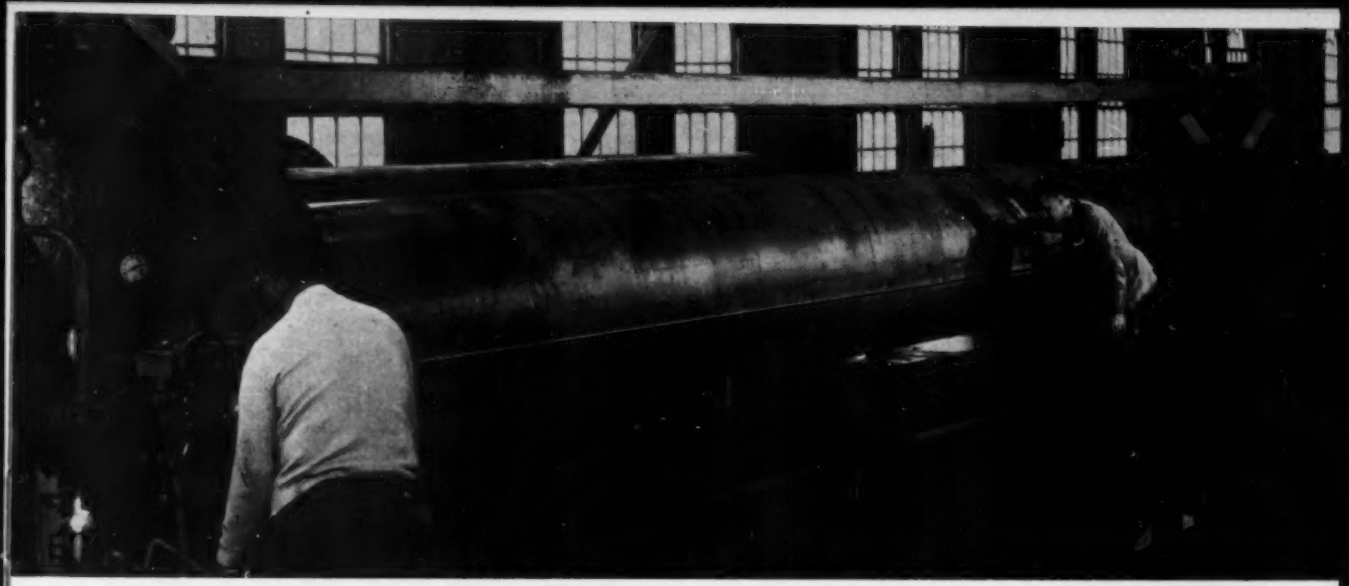


PIPE BRIDGE for the Philadelphia Suburban Water Company. This section, 83 ft between field seams, will span railroad tracks. The pipe is 24-in. ID Bethlehem Tar-Enameled Water Pipe.

4. LEAKPROOF JOINTS—It makes a tight line, with joints made by mechanical couplings, welding or riveting. It spans most washouts due to floods or other causes.

5. RESILIENCE—Bethlehem Steel Pipe has the resilience to give under soil movement. It is immune to surface vibrations caused by heavy vehicular traffic, making possible years of dependable service.

6. 40-FT. LENGTHS—Bethlehem Steel Pipe generally comes in 40-ft. lengths. This reduces the laying cost, as only 132 joints are required per mile, as compared to 300 or more joints per mile required by pipe of other materials. All diameters, 22 in. and larger. Wall thickness as required.



HYDROSTATIC TEST assures you that Bethlehem Tar-Enameled Steel Pipe meets AWWA requirements for strength and water-tightness. This test is usually equivalent to twice the working pressure.

COLORADO SPRINGS, COLO., water-supply system includes a 17-mile line of 30-in. Bethlehem Tar-Enameled Steel Pipe.

NEW ORLEANS water system expanded and improved with 60,000 ft of 50-in. Bethlehem Tar-Enameled Steel Pipe, in straight sections and bends.

BETHLEHEM STEEL COMPANY *General Offices:* **BETHLEHEM, PA.**

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BETHLEHEM STEEL

Loss of Head in Pipes and Fittings

THERE are numerous times when a water works engineer wishes to know the loss in head in some particular line. Information on this subject is not lacking but often is scattered in various texts and magazines. Diagrammatic charts, prepared by the application of the Hazen-Williams, and Scobey formulas for flow of water in pipes have been developed as aids to the solution of problems involving loss of head. Tables and charts of loss of head through valves and fittings are likewise available from various sources and authors.

In an attempt to bring these data tables, charts, and diagrams together in one place the following collection is presented. Together with such running comment as is necessary, the information in the following pages should be sufficient to solve any problem in loss of head.

Flow of Water in Pipe[1]

The carrying capacity of a pipe line may be regarded as the index of its hydraulic efficiency. Selection of the most suitable hydraulic characteristics to satisfy the economics of a given installation usually involves consideration of several alternate procedures, and comparisons of their respective characteristics, before the most appropriate choice can be made. These comparisons can only be as valid as the underlying hydraulic assumptions they depend on, hence the importance of suitable expressions correctly formulating the proper relationships involved.

Many studies have been made to determine these relationships, and many formulae developed to express them. In 1775, Chezy, a French engineer, offered his well-known formula for the flow of water in open channels and closed conduits:

$$V = C\sqrt{r\,s},$$

"C" being a coefficient at first supposed to have a constant value, but now known to vary with the velocity, slope, hydraulic radius, and with some factor representing influences of contact surfaces. The Kutter elaboration of the Chezy formula reads:

$$V = \left\{ \frac{\dfrac{1.811}{n} + \dfrac{0.00281}{s} + 41.66}{1 + \dfrac{\dfrac{n}{\sqrt{r}}\left[41.66 + \dfrac{0.00281}{s}\right]} \right\} \sqrt{r\,s},$$

in which "C" of the Chezy formula has been developed into the bracketed expression shown at left, which also introduces a new variable "n", supposed to represent all retarding influences. Unfortunately, however, the value of "n" varies somewhat for pipe, both with size and velocity. Now if we examine for a moment the basic formula

$$h_f = \frac{f\,L\,V^2}{2gd}$$

which can be established by the usual hydraulic reasoning, we find the Chezy formula recognizable in it, and also the well-known formulas of Darcy Weisbach and Fanning. All these suffer in a basic respect, in that the friction "constant" does not remain constant throughout the range of application. In the early 1900's these discrepancies began to create a definite reaction against the use of the basic simple assumption that $V = C\sqrt{r\,s}$*, culminating in the presentation of the Williams-Hazen formula. In other words, more critical scrutiny and application of available data indicated that the loss of head does not vary as the square of the velocity, but in accordance with a value lying somewhere between 1.70 and 2.00. It is now fairly well understood that theirs (i. e., the exponential type of formula) is preferable to any other form; also that losses within most closed conduits at velocities within the range of ordinary extremes of service require what Scobey calls "a compromise value somewhat less than 2.00".

The Williams-Hazen formula is now widely accepted, and reads:

$$V = C\,r^{0.63}\,S^{0.54}\,.001^{-0.04}, \text{ where}$$

V = mean velocity of flow, in feet per second.
C = "coefficient of retardation," so-called. when H = 1000s, x = 2, and y = 1.
r = mean hydraulic radius of the pipe, or diameter D ÷ 4, in feet.
s = hydraulic grade or slope, in feet per foot of length of a pipe of uniform size.

or

$$S^{0.54} = \frac{V}{C\left[\frac{D}{4}\right]^{0.63} \times 0.001^{-0.04}}$$

$$= \frac{4^{0.63}\,V}{1.318\,C\,D^{0.63}}$$

$$S = \frac{4^{1.167}\,V^{1.852}}{1.318^{1.852}\,C^{1.852}\,D^{1.167}}$$

$$= \frac{3.0236\,V^{1.852}}{C^{1.852}\,D^{1.167}}$$

$$S_{1000}\left[\begin{matrix}\text{Loss of Head}\\ \text{in Feet, per}\\ \text{1,000 Feet}\end{matrix}\right] = \frac{3023.6\,V^{1.852}}{C^{1.852}\,D^{1.167}}$$

$$= K\frac{V^{1.852}}{D^{1.167}}$$

when $\begin{cases} C = 90 & 95 & 100 & 105 & 110 & 115 \\ K = .727 & .657 & .598 & .546 & .501 & .461 \end{cases}$

or $\begin{cases} C = 120 & 125 & 130 & 135 & 140 \\ K = .426 & .395 & .367 & .343 & .321 \end{cases}$

Loss of Head Charts Based on the Hazen-Williams and Scobey Formulas

In the following pages appear four charts (Fig. 1, 2, 3, 4) for determining loss of head in lineal pipe lines. The first three were developed from the Hazen-Williams Formula and apply to any pipe. The last was developed from the Scobey formula and is applicable to concrete pipes.

Figure 1 was prepared by William P. Creager,[2] Chief Engineer, The Power Corporation of New York, and was originally published by John Wiley and Sons in the Hydro-Electric Handbook, by Creager and Justin.

Figures 2 and 3 are nomographs and were prepared for an article on the Hardy Cross Method by D. R. Taylor [3]. Figure 4, also a nomograph, was prepared by J. R. Griffiths, of the U. S. Navy[4].

Values of the Coefficient "C"

Although the second and third charts are for definite values of the friction coefficient "C" in the Hazen-Williams Formula, the first chart by Creager may be used for any value of "C," if that value is known.

Recommended values of "C" for the Hazen-Williams Formula were given by Hazen and Williams in their book, "Hydraulic Tables"[5]. These values for straight line conduits are shown in Table 1.

TABLE 1

Table of C Values Cast Iron Pipe

Diameter Inches	Age in Years* 0	5	10	20	30	40	50
4	130	118	107	89	75	64	55
8	130	119	109	93	83	73	65
12	130	120	111	96	86	77	70
16	130	120	112	98	87	80	72
24	130	120	113	100	89	81	74
30	130	120	113	100	90	83	76
36	130	120	113	100	90	83	76
40	130	120	113	100	90	83	77
60	130	120	113	100	90	83	77

*Cleaning old pipe increases the C value.

Riveted Steel Pipe
  Light riveted steel pipe—
    Avg. C for any age = 10 year C.I.P.
  Heavy riveted steel pipe—
    Avg. C for any age = 20 year C.I.P.
Welded Steel Pipe
  Equivalent to 5 yr. or older C.I.P.
Wood Stave Pipe
  Best C = 145
  Probable Average C = 120
  Worst C = 110
Concrete Pipes and Pressure Tunnels
  Metal Forms
    Best workmanship— C = 150
    Probable workmanship—C = 140
    Worst workmanship— C = 120
  Wood Form—Monolithic
    Best workmanship— C = 130
    Probable workmanship—C = 120
    Worst workmanship— C = 90
  If Slimed
    20 points below Best
    15 points below Average
    10 points below Worst

In addition to the values in Table 1 the following values of the friction coefficient have been published by the National Tube Co.[6]

These values of the coefficient "C" are to be used in the Hazen-Williams formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient
"Duroline"	148*†
Wrought Steel	140
Small Brass and Copper	130
Cast Iron	130
Concrete	120
Wood Stave	120
Riveted Steel	110
Vitrified Pipe	110
Brick Sewers	100

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe. —Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumulation of corrosion products, and tuberculation. However, in case of cement or enamel lined pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Useful Loss of Head Tables

D. R. Taylor[3] gives two tables on loss of head. The first (Table 2) gives values for use in the formula

*Convertible into the general formula $H = \frac{V_x}{D^y}$;

$$S = R Q_m^{1.85}$$

where S = loss of head per 1000 ft.
R = resistance factor depending on size and smoothness of pipe.
Q_m = quantity of flow in gal. per min.

Values in the table are given as "k" values which are equal to 100,000 times the "R" value.

Table 3 gives "R" values when the flow quantity is expressed in mil. gal. per day, for the formula $S = RQ_s^{1.85}$

where S = loss of head per 100 ft. of pipe.
R = resistance factor.
Q_s = quantity flow in mgd.

In Table 4 are listed pipe friction for various size pipes and velocities.[5]

Loss of Head for Valves and Fittings

The following discussion and its accompanying chart titled Friction Chart for Valves and Fittings have been taken from Crane Company's "Engineering Data on Flow of Fluids in Pipes"[7]"

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves

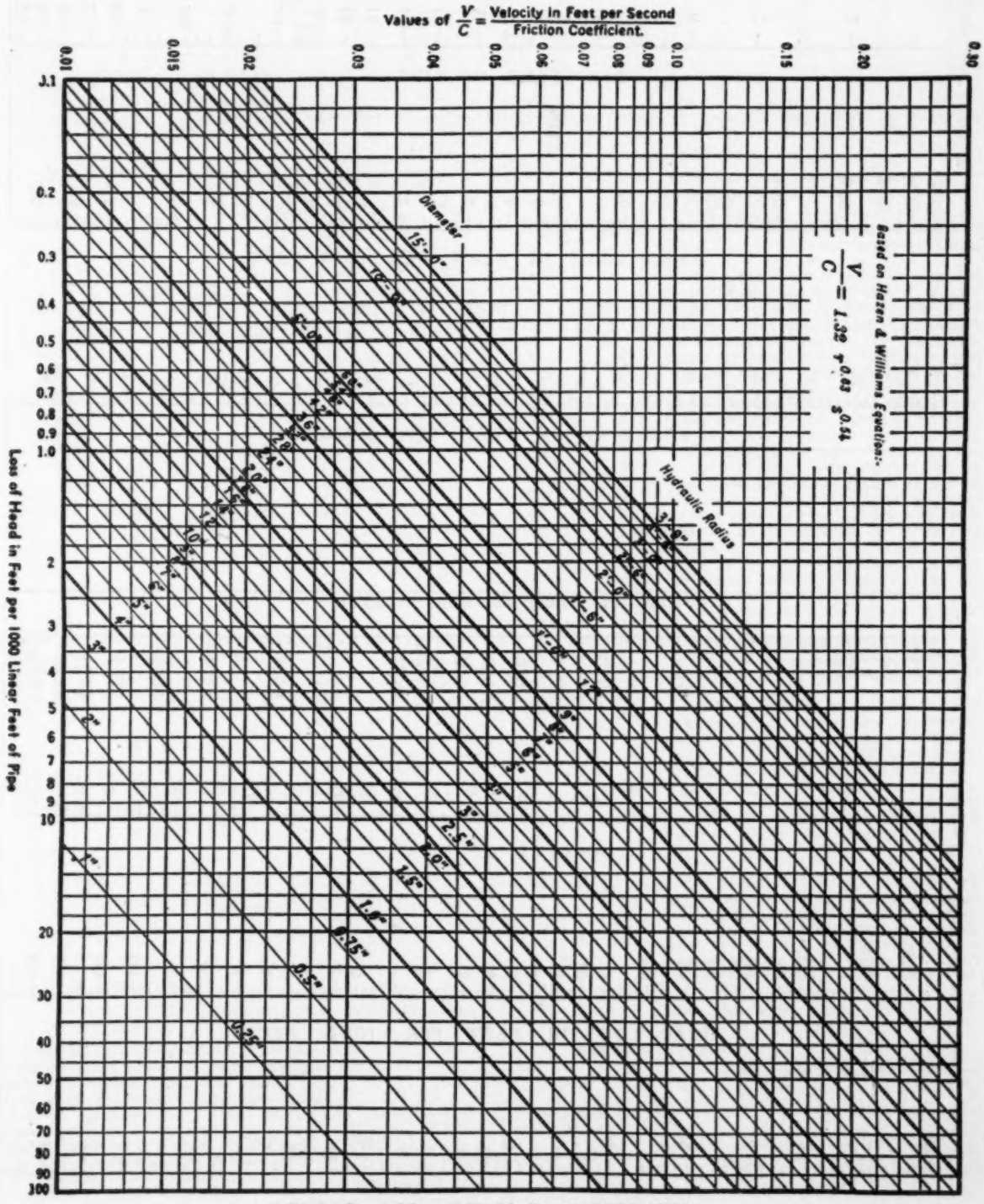

Fig. 1—Chart of Loss of Head in Feet per 1000 ft. of Pipe

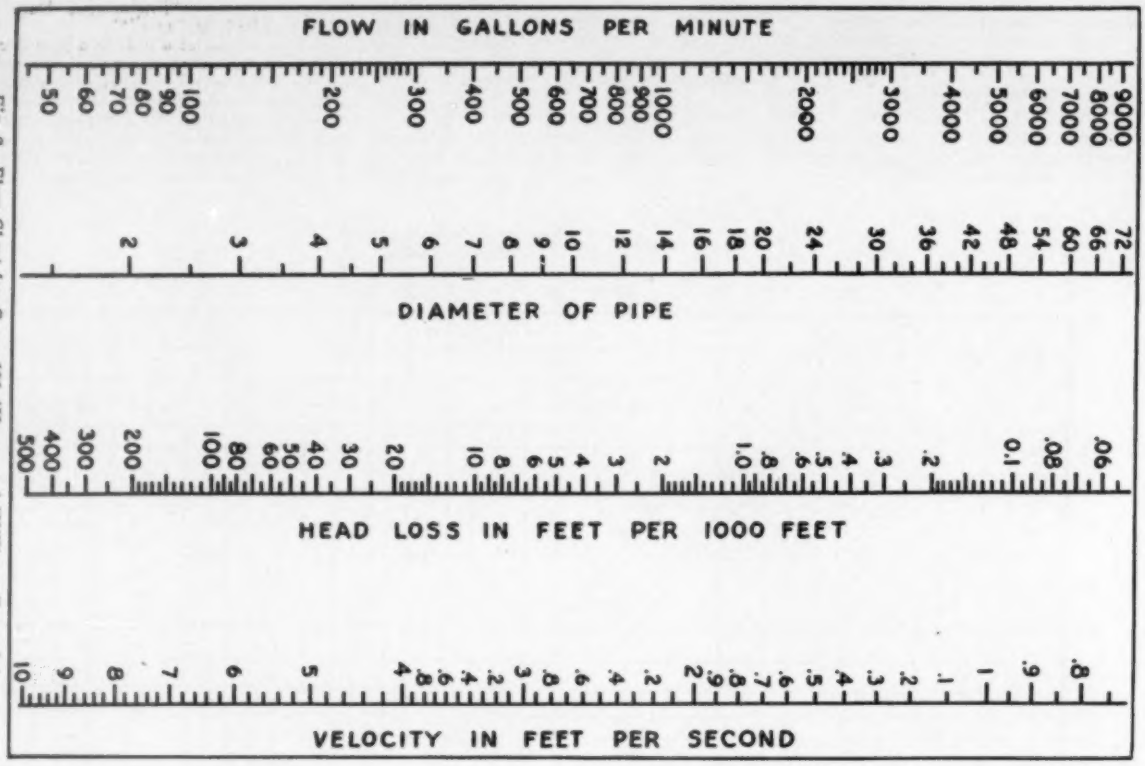

Fig. 2—Flow Chart for C = 100 (Hazen and Williams Formula)

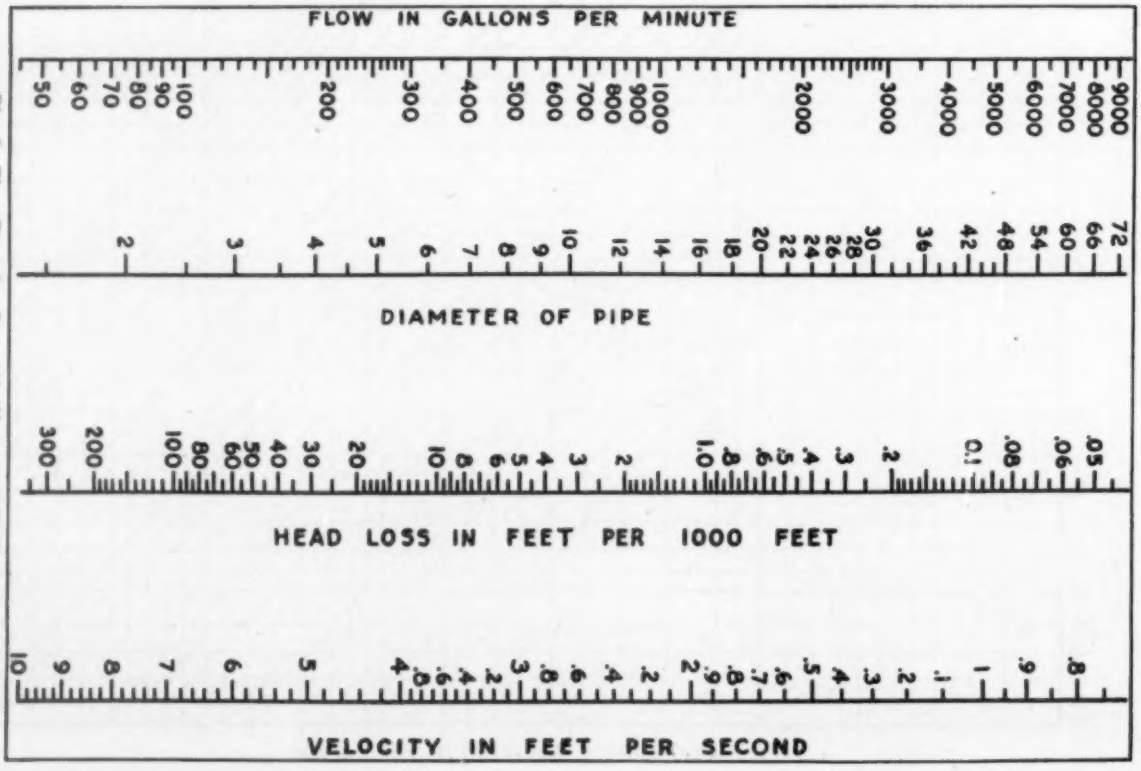

Fig. 3—Flow Chart for C = 120 (Hazen and Williams Formula)

and fittings becomes a major item in the total pressure drop valve.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines."[9] Tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

TABLE 2

Values of k for 1,000 Feet of Pipe Based on the Hazen-Williams Formula

Pipe Diameter, Inches	C= 90	100	110	120	130	140
4	300	248	208	117	153	133
6	41	33.7	28.4	24.2	20.9	18.2
8	10	8.4	7.0	6.0	5.2	4.5
10	3.4	2.8	2.4	2.0	1.7	1.5
12	1.5	1.2	1.0	.83	.71	.62
14	.66	.55	.46	.39	.34	.30
16	.35	.29	.24	.20	.18	.15
18	.20	.16	.14	.12	.10	.09
20	.12	.10	.08	.07	.06	.05
24	.049	.04	.03	.03	.02	.02
30	.016	.013	.011	.010	.008	.007
36	.0067	.0054	.0046	.0039	.0034	.0030

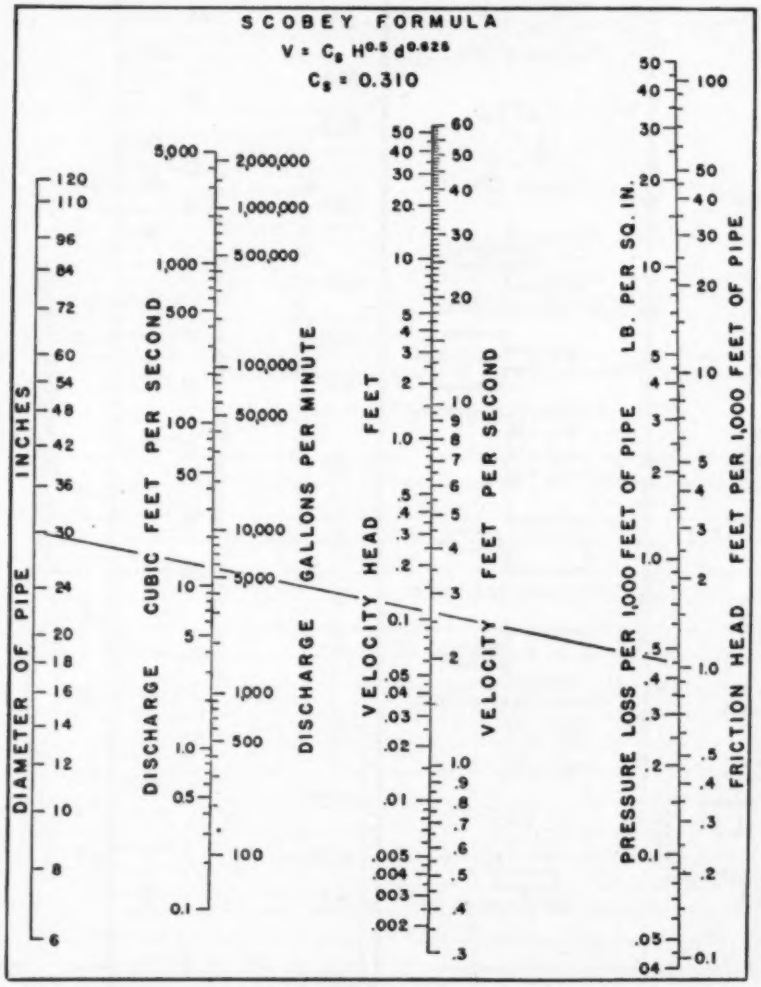
SCOBEY FORMULA
V = Cs H0.5 d0.625
Cs = 0.310
DIAMETER OF PIPE INCHES
DISCHARGE CUBIC FEET PER SECOND
DISCHARGE GALLONS PER MINUTE
VELOCITY HEAD FEET
VELOCITY FEET PER SECOND
PRESSURE LOSS PER 1,000 FEET OF PIPE LB. PER SQ. IN.
FRICTION HEAD FEET PER 1,000 FEET OF PIPE

Fig. 4—Flow of Water in Concrete Pipe

Realizing the need for definite data covering this subject, Crane Co. conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.) from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow were produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual.

Age Factors For Fig. 5

	Age In Years						
	New	10	15	20	30	50	75
Fire Protection Mains—No Domestic Draft	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Public and Fire Protection Mains with Domestic Draft							
Surface Water							
Slight Tuberculation	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Moderate Tuberculation	0.7	1.2	1.7	2.1	2.9	3.5	3.9
Severe Tuberculation	0.7	1.6	2.4	3.1	4.5	5.2	5.5
Well Water	0.7	1.6	2.4	3.1	4.5	5.2	5.5

These age factors for cast-iron mains are adapted from the results of an investigation by a committee of the New England Water Works Association[33].

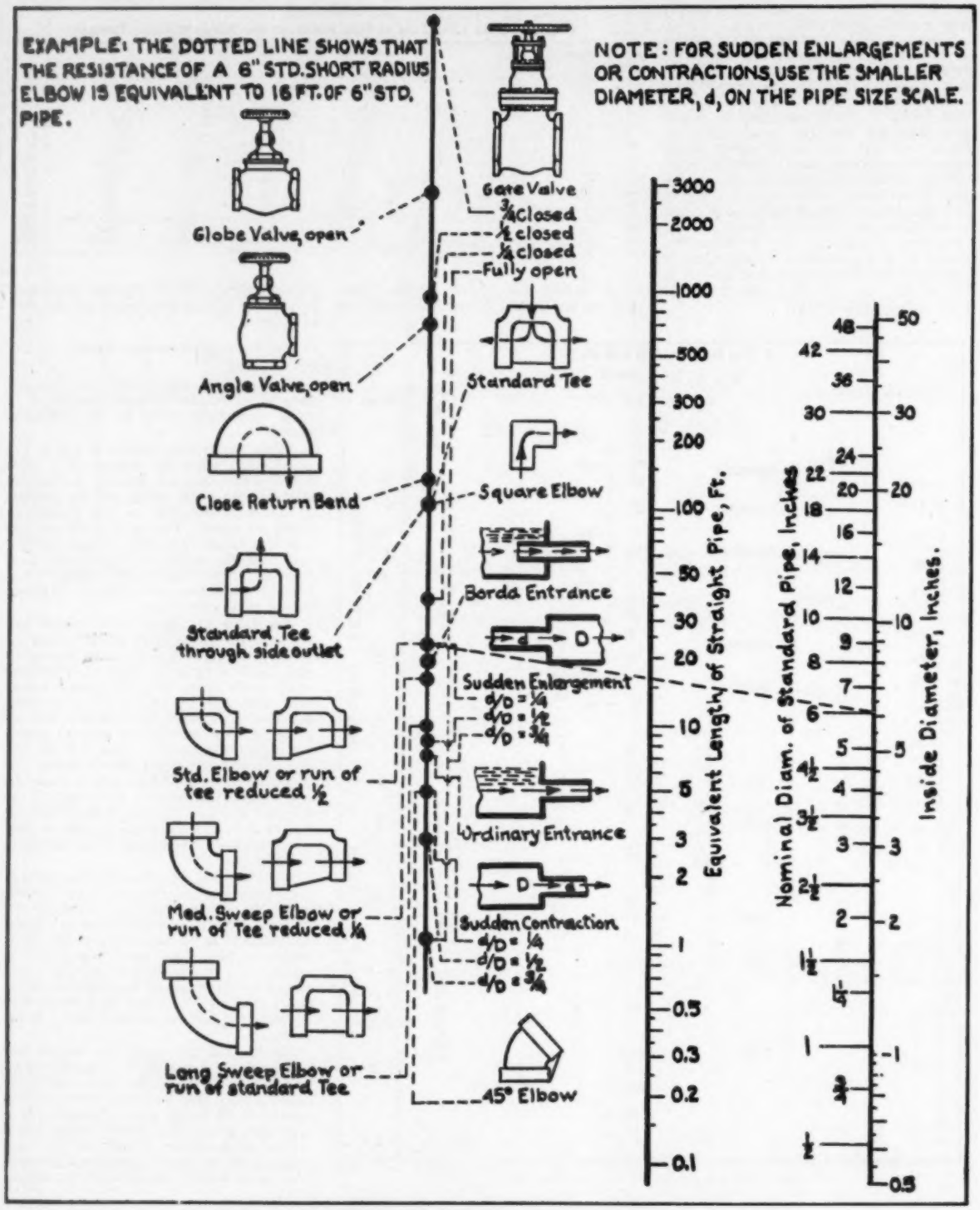

Fig. 5—Friction Chart for Valves and Fittings
*(For Converting These Units Into Equivalent Added Length of Pipe)**

*Note: These equivalents, in terms of length of pipe to be added in computations, were derived for steel pipe in good condition. In applying the chart to cast-iron pipe divide the equivalent length of steel pipe by 1.64 times the most appropriate age factor found in Table 5 of "Age Factors" for C.I. mains.

TABLE 3

Values of "R" for 1,000 Ft. of Pipe Based on Hazen and Williams Formula

d—Inches	Head Loss in Ft.: S=R x $Q^{1.85}$ per 1,000 ft. (Q in m.g.d.) c=70	c=80	c=90	c=100	c=110	c=120	c=130	c=140
4.....	860.69	672.31	540.67	444.91	373.00	317.53	273.83	238.76
6.....	119.44	93.30	75.03	61.74	51.76	44.06	38.00	33.13
8.....	29.42	22.98	18.48	15.21	12.75	10.85	9.36	8.16
10.....	9.93	7.75	6.24	5.13	4.30	3.66	3.16	2.75
12.....	4.08	3.19	2.57	2.11	1.77	1.51	1.30	1.13
14.....	1.925	1.504	1.209	0.995	0.834	0.710	0.612	0.534
16.....	1.007	0.787	0.633	0.521	0.437	0.372	0.320	0.279
18.....	0.567	0.443	0.356	0.293	0.246	0.209	0.180	0.157
20.....	0.3390	0.2648	0.2130	0.1753	0.1469	0.1251	0.1079	0.0941
24.....	0.1396	0.1091	0.0877	0.0722	0.0605	0.0515	0.0444	0.0378
30.....	0.0471	0.0368	0.0296	0.0244	0.0204	0.0174	0.0150	0.0151
36.....	0.01939	0.01514	0.01218	0.01002	0.00840	0.00715	0.00617	0.00528
42.....	0.00915	0.00715	0.00575	0.00473	0.00397	0.00338	0.00291	0.00254
48.....	0.004774	0.003729	0.002999	0.002468	0.002057	0.001761	0.001519	0.001324
60.....	0.001611	0.001258	0.001012	0.000833	0.000698	0.000594	0.000513	0.000447
66.....	0.001013	0.000791	0.000636	0.000524	0.000439	0.000374	0.000322	0.000281

This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows by F. E. Giesecke.(5)

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, the friction chart for valves and fittings, shown in Fig. 5, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

In using Fig. 5, it must be remembered that the values were derived for steel pipe in good condition. In applying the chart to cast iron pipe divide the equivalent length of steel by 1.64 times the appropriate age factor in the table opposite Fig. 5.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the coefficients of the formula.

$$H_1 = K\frac{V^2}{2g}$$

where H_1 = Loss of head in ft.
K = Coefficient
V = Velocity in ft. per sec.
2g = 64.4

Coefficients for use in this formula are shown in Table 5.

Burns and McDonnell, Engineers, prepared the chart (Fig. 6) by which the loss in head in fittings and valves may be determined.

In Fig. 6, to determine loss of head—assume flow (Q) to be 5 ft. per sec. through a fitting of 12 in. diameter. From Q = AV, the velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g}$ = 0.7 ft.

Applied to 90 degree bend head loss is 0.25 × 0.7 = 0.18 ft. For a tee 1.25 × .7 = 0.87 ft.

(Note—Correspondence with the producers of this chart cites values for check valves far in excess of the 0.5 indicated.—*Ed.*)

Another method of determining loss of head in fittings and valves is given in Table 6 with approximate head losses for various fittings. Exact losses cannot be determined due to variation in construction details.

TABLE 5

Loss of Head Coefficients for Fittings and Valves

Type	Coefficient	Authority
Globe Valves	10	Ref. No. 7
Angle Valve	5	Ref. No. 7
Return Bend	2.2	
Tee	1.8	Ref. No. 9
Short Radius Elbow	.9	Ref. No. 9
Med. Radius Elbow	.75	Ref. No. 7
Long Radius Elbow	.60	Ref. No. 10
Gate Valve (Open)	.19	Av. Ref. No. 11
¼ Closed	1.15	Av. Ref. No. 11
½ Closed	5.6	Av. Ref. No. 11
¾ Closed	24.0	Av. Ref. No. 11
Borda Entrance	.83	Av. Ref. No. 12
Sudden Enlargement		
d/D — ¼	.92	Ref. No. 12
d/D — ½	.56	Ref. No. 12
d/D — ¾	.19	Ref. No. 12
Ordinary Entrance	.5	Ref. No. 12
Sudden Contraction		
d/D = ¼	.42	Ref. No. 12
d/D = ½	.33	Ref. No. 12
d/D = ¾	.19	Ref. No. 12
45° Elbow	.42	Ref. No. 10

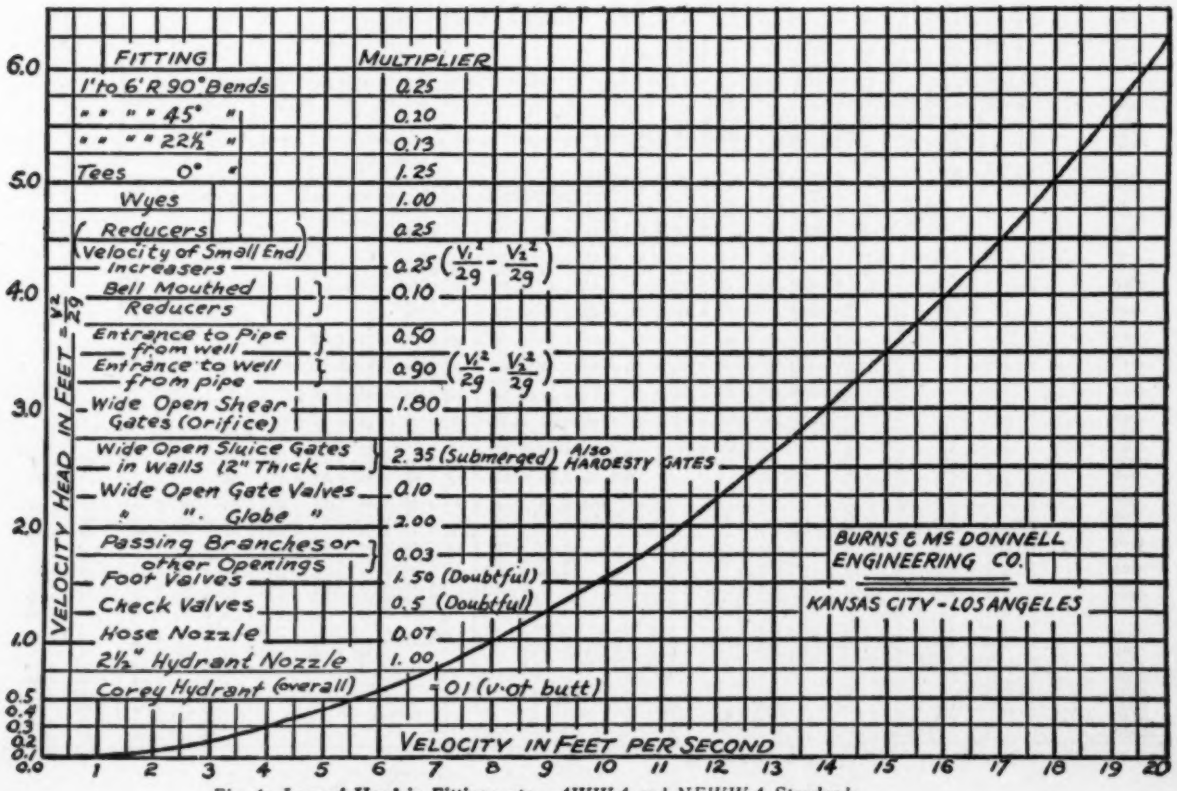

Fig. 6—Loss of Head in Fittings, etc.—AWWA and NEWWA Standards

TABLE 4

Friction of Water in Pipes

The pipe frictions shown in the following tables are taken by permission from the more complete copyright tables by Williams and Hazen, published by John Wiley & Sons, and these values are recommended for use in figuring pipe frictions.

Loss of Head in Feet Due to Friction, per 100 feet of 15 year old Ordinary Iron Pipe

U.S. Gal's per Min.	1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
10	3.72	11.7	2.14	3.05	1.57	1.43	1.02	0.50	0.65	0.17	0.45	0.07
15	5.60	25.0	3.2	6.50	2.36	3.0	1.53	1.0	0.98	0.36	0.68	0.15
20	7.44	42.0	4.29	11.1	3.15	5.2	2.04	1.82	1.31	0.61	0.91	0.25
25	9.30	64.0	5.36	16.6	3.94	7.8	2.55	2.73	1.63	0.92	1.13	0.38
30	11.15	89.0	6.43	23.5	4.72	11.0	3.06	3.84	1.96	1.29	1.36	0.54
35	13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.1	2.29	1.72	1.59	0.71
40	14.88	152.0	8.58	40.0	6.3	18.8	4.08	6.6	2.61	2.20	1.82	0.91
45			9.65	50	7.08	23.2	4.60	8.2	2.94	2.80	2.05	1.15
50			10.72	60	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38
70			15.01	113	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57
90					14.17	84.0	9.19	29.4	5.88	9.8	4.09	4.08
100					15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96
120					18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0
140					22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2
160							16.34	86.0	10.46	29.0	7.26	11.8
180							18.38	107.0	11.76	35.7	8.17	14.8
200							20.42	129.0	13.07	43.1	9.08	17.8
220							22.47	154.0	14.38	52.0	9.99	21.3
240							24.51	182.0	15.69	61.0	10.89	25.1
260							26.55	211.0	16.99	70.0	11.80	29.1
280									18.30	81.0	12.71	33.4
300									19.61	92.0	13.62	38.0

U. S. Gal's per Min.	4" Pipe		5" Pipe		6" Pipe		8" Pipe		10" Pipe		12" Pipe		14" Pipe		15" Pipe		16" Pipe		20" Pipe		24" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
40	1.02	0.22																				
45	1.17	0.28																				
50	1.28	0.34																				
70	1.79	0.63	1.14	0.21																		
75	1.92	0.73	1.22	0.24																		
100	2.55	1.22	1.63	0.41	1.14	0.14																
120	3.06	1.71	1.96	0.58	1.42	0.25																
125	3.19	1.86	2.04	0.64	1.48	0.28																
150	3.84	2.55	2.45	0.88	1.71	0.32																
175	4.45	3.44	2.86	1.18	2.00	0.48																
200	5.11	4.40	3.27	1.48	2.28	0.62																
225	5.77	5.45	3.67	1.86	2.57	0.74																
250	6.40	6.72	4.08	2.24	2.80	0.92	1.60	0.22														
270	6.90	7.70	4.42	2.60	3.03	1.13	1.70	0.25														
275	7.03	7.99	4.50	2.72	3.06	1.15	1.73	0.27														
300	7.66	9.30	4.90	3.14	3.40	1.29	1.90	0.32														
350	8.90	12.32	5.72	4.19	3.98	1.75	2.20	0.42														
400	10.21	16.00	6.54	5.40	4.54	2.21	2.60	0.54														
450	11.50	19.80	7.35	6.70	5.12	2.65	2.92	0.68	1.80	0.21												
470	12.10	22.40	7.70	7.22	5.49	2.90	3.07	0.75	1.92	0.24												
475	12.20	22.96	7.76	7.42	5.55	2.95	3.10	0.76	1.94	0.25												
500	12.77	24.00	8.17	8.12	5.60	3.30	3.20	0.82	2.04	0.28	1.42	0.11										
550			8.99	9.60	6.16	3.93	3.52	0.97	2.25	0.33	1.57	0.14										
600			9.80	11.30	6.72	4.70	3.84	1.14	2.46	0.39	1.71	0.15										
650			10.62	13.20	7.28	5.40	4.16	1.34	2.66	0.46	1.85	0.19	1.37	0.09								
700			11.44	15.10	7.84	6.20	4.46	1.54	2.86	0.52	2.00	0.22	1.47	0.10								
750			12.26	17.20	8.50	7.00	4.80	1.74	3.06	0.59	2.13	0.24	1.58	0.11								
800					9.08	8.00	5.12	1.97	3.28	0.67	2.27	0.27	1.68	0.13								
850					9.58	8.95	5.48	2.28	3.48	0.75	2.41	0.31	1.79	0.14								
900					10.30	10.11	5.75	2.46	3.68	0.83	2.56	0.34	1.89	0.16								
950					10.72	10.80	6.06	2.87	3.88	0.91	2.70	0.38	2.00	0.18	1.73	0.12						
1000					11.32	12.04	6.40	3.02	4.08	1.01	2.84	0.41	2.10	0.19	1.82	0.14						
1050					11.90	13.30	6.70	3.21	4.29	1.09	2.98	0.44	2.20	0.22	1.91	0.16						
1100					12.50	14.31	7.03	3.51	4.50	1.20	3.13	0.49	2.31	0.23	2.00	0.17						
1150					12.95	15.60	7.35	3.84	4.71	1.34	3.27	0.53	2.42	0.25	2.09	0.18						
1200					13.52	16.69	7.67	4.15	4.91	1.46	3.41	0.57	2.52	0.26	2.18	0.19						
1250					14.10	18.50	8.00	4.45	5.11	1.51	3.55	0.62	2.63	0.29	2.28	0.20	1.99	0.15				
1500							9.60	6.27	6.10	2.09	4.20	0.85	3.15	0.39	2.73	0.28	2.39	0.21			1.42	0.05
2000							12.70	10.71	8.10	3.65	5.60	1.43	4.20	0.66	3.64	0.54	3.19	0.39			1.77	0.07
2500									10.10	5.33	7.00	2.28	5.25	1.01	4.55	0.72	3.99	0.56				
3000									12.10	7.80	8.40	3.15	6.30	1.47	5.46	1.12	4.79	0.80	3.08	0.27	2.13	0.10
3500									14.10	10.08	9.80	4.10	7.35	1.81	6.37	1.43	5.59	1.04	3.59	0.35	2.49	0.14
4000											11.35	5.32	8.40	2.47	7.28	1.85	6.38	1.34	4.10	0.45	2.85	0.18
4200											11.93	6.00	8.82	2.80	7.64	2.08	6.72	1.45	4.32	0.50		
4500											12.78	6.90	9.45	3.22	8.19	2.23	7.20	1.65	4.62	0.56	3.20	0.22
5000											14.20	8.40	10.50	3.92	9.10	2.78	7.96	2.02	5.13	0.68	3.54	0.27
5500													11.55	4.65	10.01	3.30	8.78	2.39	5.64	0.82	3.90	0.33
6000													12.60	5.50	10.92	3.90	9.56	2.60	6.15	0.96	4.25	0.38
6500													13.65	6.45	11.83	4.55	10.36	3.32	6.66	1.06	4.61	0.45
7000													14.70	7.15	12.74	5.08	11.12	3.68	7.18	1.28	4.97	0.52
7200															13.10	5.45	11.50	3.96	7.38	1.35		
7500															13.65	5.90	11.95	4.28	7.66	1.45	5.32	0.59
8000																			8.17	1.63	5.68	0.66
8500																			8.68	1.83	6.03	0.74
9000																			9.20	2.04	6.35	0.81
9500																			9.70	2.23	6.74	0.91
10000																			10.40	2.53	7.07	0.98

Vel.—Velocity ft. per second. Fric.—Friction head in feet.

TABLE 7

Values for Determining Head Losses for Fittings

Diameter of fittings	1	1½	2	2½	3	4	5	6	7	Inches
Constant	2.5	3.75	5	6.25	7.5	10	12.5	15	17.5	Constant
	8	9	10	11	12	15	16	18	20	Inches
	20	22.5	25	27.5	30	37.5	40	45	50	Constant

Multipliers for Different Fittings

45° Ell	0.26	*Angle Globe Valve	5.0	Reciprocating piston	20.0
90° Ell	1.0	*Check Valve	3.0	Turbine wheel type (Double flow balanced)	8.3
Tee	2.0	Water Meters:		Venturi Meters:	
*Gate Valve	0.37	Disk or wobble plate type	9.0	Ratio of $d_2/d_1 = 0.5$	2.66
*Globe Valve	3.33	Rotary (disk or star shape, as piston)	13.3	Ratio of $d_2/d_1 = 0.4$	5.66

*Multipliers are for valves operating wide open.

In Table 6 under each size fitting is a constant which, multiplied by the multiplier for each kind of fitting in the pipe line, will give the additional length in feet to be added to the actual length of discharge pipe or pipe line. Take, for example, a 10-inch pipe line 300-feet long with 2-90° ells, 1-gate valve, 1-check valve and a venturi meter having a ratio of $d_2/d_1 = 0.5$. The additional length for head loss in these fittings is made up as follows: 2-90° ells 25-feet each, 1-gate valve 9-feet, 1-check valve 75-feet, 1-venturi meter 66-feet, making a total of 200-feet additional which must be added to the 300-feet actual length, or the equivalent of 500-feet of new 10-inch pipe line upon which the friction head loss must be figured in order to arrive at the total loss in the pipe line and fittings.

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Equation of Pipes

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters; thus one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power. This table is calculated on this basis. The figures opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger; thus one 4-inch equals 5.7 two-inch.

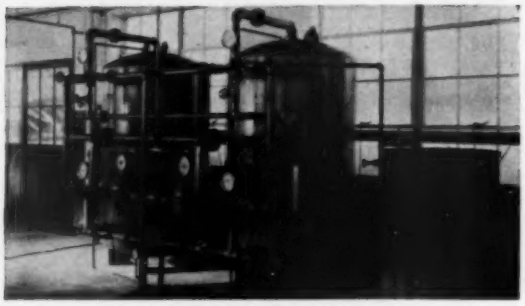
Dia. in.	1	2	3	4	5	6	7	8	10	12	14	16	18	20	24	30	36
2	5.7	1.															
3	15.6	2.8	1.														
4	32.	5.7	2.1	1.													
5	55.9	9.9	3.6	1.7	1.												
6	88.2	15.6	5.7	2.8	1.6	1.											
7	130.	22.9	8.3	4.1	2.3	1.5	1.										
8	181.	32.	11.7	5.7	3.2	2.1	1.4	1.									
10	316.	55.9	20.3	9.9	5.7	3.6	2.4	1.7	1.								
11	401.	70.9	25.	12.5	7.2	4.6	3.1	2.2	1.3								
12	499.	88.2	32.	15.6	8.9	5.7	3.8	2.8	1.6	1.							
13	609.	108.	39.1	19.	10.9	7.1	4.7	3.4	1.9	1.2							
14	733.	130.	47.	22.9	13.1	8.3	5.7	4.1	2.3	1.5	1.						
15	787.	154.	55.9	27.2	15.6	9.9	6.7	4.8	2.8	1.7	1.2						
16		181.	65.7	32.	18.3	11.7	7.9	5.7	3.2	2.1	1.4	1.					
17		211.	76.4	37.2	21.3	13.5	9.2	6.6	3.8	2.4	1.6	1.2					
18		243.	88.2	43.	24.6	15.6	10.6	7.6	4.3	2.8	1.9	1.3	1.				
19		278.	101.	49.1	28.1	17.8	12.1	8.7	4.8	3.2	2.1	1.5	1.1				
20		316.	115.	55.9	32.	20.3	13.8	9.9	5.7	3.6	2.4	1.7	1.3	1.			
22		401.	146.	70.9	40.6	25.7	17.5	12.5	7.2	4.6	3.1	2.2	1.7	1.3			
24		499.	181.	88.2	50.5	32.	21.8	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1.		
30								27.2	15.6	10.0	6.7	4.8	3.6	2.8	1.75	1.0	
36									24.6	15.6	10.6	7.6	5.7	4.3	2.76	1.6	1.0

Roberts Filter *means . . .*

MUNICIPAL WATER PURIFICATION

The combined capacity of Roberts-equipped filtration plants is well over 5 billion gallons (5,000,000,000) per day. Regardless of the size of the plant or the nature of the filtration problem, Roberts Filter can be depended upon for equipment that is reliable in years of service.

INDUSTRIAL WATER RECTIFICATION



Water treatment has long been a specialty of Roberts Filter. Zeolite water softeners are guaranteed to meet all requirements for which recommended, and are available in a wide range of capacities. Roberts water conditioning equipment is widely used to control precisely the desired chemical content of water for industrial use.

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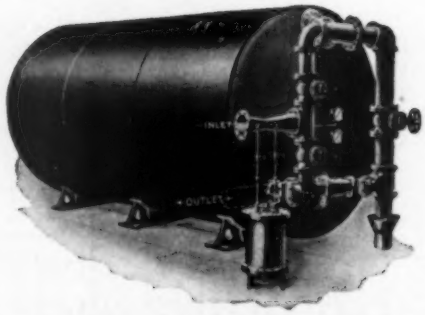
The combination of thoroughly clarified water and efficient recirculation are features for which Roberts pools are famous. Systems for both outdoor and indoor pools are designed and installed by men long experienced in the conditions peculiar to a successful swimming pool installation.

PRESSURE FILTERS



Closed pressure filters have wide usage where gravity filters are not justified. Roberts vertical filters are available in standard types from 12″ to 96″ diameter; horizontal pressure filters are all 8′0″ in diameter and in varying lengths from 10′0″ to 25′0″.

When you think of good water—think of Roberts Filter

MECHANICAL EQUIPMENT BY ROBERTS FILTER MFG. CO. DARBY, PENNA.

Roberts Filter

Manufacturing Company • Darby, Pennsylvania

Rapid Sand Filter Washing

Results accomplished by old and new methods

By H. J. KRUM and I. M. GLACE
Mr. Krum is Supt. of Filtration, Allentown, Pa.
and Mr. Glace is Cons. Sanitary Engr., Harrisburg, Pa.

THE authors of this paper, although having no official connections, have nevertheless cooperated for years on the solution of the many difficulties incident to the proper maintenance of public water supplies and the collection and disposal of sewage, including certain research and operating problems. The care of filters, naturally, has been one of the matters considered.

This association has been unusually beneficial to both authors and the more effective, it is felt, because one author (Krum) has had available a large and well equipped laboratory for chemical and bacteriological studies and, as chief operator of a ten million gallon rapid sand filter plant as well as several smaller swimming pool filters, has been able to install for experimental purposes many devices of varying kinds, and to put into practice a number of improved operating procedures.

Although the authors confess to differences of opinion on some of the practices of the profession, they find themselves in complete agreement on the desirability of better facilities for the cleansing of the media of filter units, and on the efficiency of the so-called surface-wash.

The data and conclusions presented herein represent a consolidation of ideas and opinions based on detailed research at one plant and on general observations at plants over a wide area.

Past Practices

For the sake of clarifying this discussion, and in an attempt to indicate briefly the struggle of the profession to solve this knotty problem of filter operation, the historical outline which follows is cited to show approximately the time periods in which certain designs and practices have been popular in the water works field:

—Prior to 1910—

In circular tub filters; with false bottoms, pipe laterals, a variety of types of strainer heads and, commonly, revolving fixed rakes, with "low" wash water rates of 8 in. to 12 in. rise per minute.

1910—1920

In rectangular concrete units; with slightly increased wash water rates, and frequently air wash as an auxiliary.

1920—1930

As in 1910-1920, but with "moderate" rates of wash up to about 30 in. rise, and with perforated lateral pipes and deeper gravel beds for better distribution.

1930—1940

As in 1910-1920, but with "high" rates of wash up to 48 in. rise per minute, a variety of filter bottoms, many of a nonmetallic character, and frequently false bottoms to replace manifolds and laterals.

Surface wash was introduced as an auxiliary to the bottom wash, with either fixed or revolving piping at the surface of the medium for such purpose. The introduction of porous plate filter bottoms, eliminating the gravel bed.

Seemingly most of the difficulties in filter washing began with the advent of the rectangular concrete box filter. This period coincided with the abandonment of the circular wooden-tub type filter and mechanical rakes.

The time periods indicated are, perforce, only approximations and considerable overlapping naturally occurs in any such classifications. As for instance, perforated pipe laterals were used as early as 1905, at the Harrisburg, Pa., works.

Mention should be made of the use of slat-bottomed units which, generally, have never been accepted by the profession because they seem to violate one of the basic principles of design; that is, the production of a uniform head at the base of the strainers, or other openings through restricted orifices.

Mention might be made, also, of the use in a number of plants of fine mesh screens, installed between the top of the gravel layer and the sand bed to prevent "upsetting" of the gravel; a condition which, it is not generally recognized, exists to some extent in practically all units not in some way protected against disturbance. This point in the filters—the junction of the sand and gravel—might well be classed as the "danger line," since a serious upset at this junction of the two media results finally in the failure of the bed to perform its functions and, ultimately, in the necessity for a complete and expensive overhauling of the affected unit. The seriousness of this problem brought forth the development of the porous-plate false bottom, a very promising improvement in design.

In addition to the listed methods of construction, an enormous amount of time and effort has been given to a study of the sizing and specific gravity of the filtering media, resulting, from a design standpoint, in the use of anthrafilt in many filters, and the use of coarser sands of a larger effective size.

All of this—revolving rakes, air wash, false bottoms, screens as gravel retainers, "high" rates, and what not, even when combined with greatly improved mixing and coagulation of chemicals—has not resulted in the design or use of any one "best" procedure, or in the prevention of mud balls, hard spots, and the necessity for the frequent expensive overhauling of the units; nor has it provided operators with means for maintaining a really *clean* filtering medium.

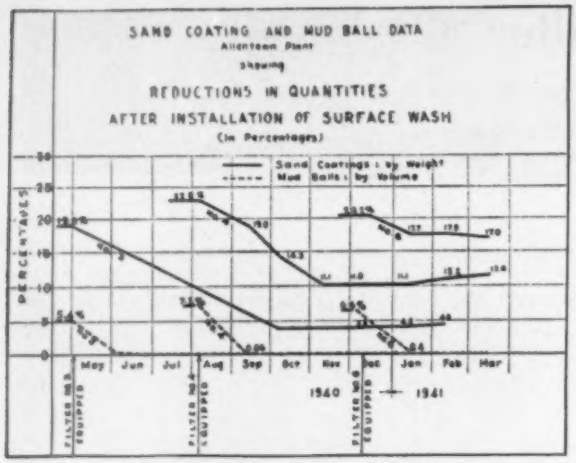
It is admitted that in some of the more carefully designed and better operated plants these interferences in filtration have been held to a minimum but so far as the water works field generally is concerned, the results are stated above.

High Wash Rates Disappointing

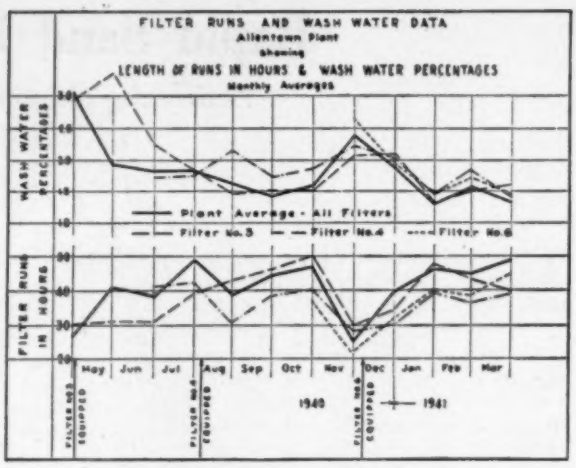
Of these various features of design, the so-called "high" wash rate seems to have been the greatest disappointment and the most misleading. A rise of as much as 48 in. per minute is exceptional but when this is expressed, as it might well be, as 4 feet per minute, the actual low velocity of such a flow can be more readily recognized. Although the actual velocities through the interstices of the expanded sand may be 2 to 3 times this stated velocity, but little sand scrubbing effect results.

The Surface Wash

Various forms of surface wash have been developed in the last half dozen years (not considering the old revolving rake in this classification) with almost universal improvement in operation.[1, 2] The development of the relatively inexpensive and easily installed Palmer Filter Bed Agitator



Graph 1—Sand Coating and Mud Ball Records
Revealing rapidity with which surface wash removes sand coatings and clears out mud balls.



Graph 2—Filter Run and Wash Records
These records fail to show wash water reduction accruing from surface wash at the Allentown plant.

has speeded up the trend towards such a form of auxiliary wash since it was introduced to the field in 1939, and first described by the inventor, a filter operator, in this magazine.[3]

The success of these various forms of surface wash is the result of the relatively high velocities of the jets issuing from the distributor arms, which velocities commonly reach from 50′ to 100′ per second or 1,000 times that of the so-called "high rate" bottom wash. The tremendous scouring action of these fire stream velocities is at once apparent.

Some Allentown Observations

When Hulbert and Herring[4] first directed the attention of the profession to the importance of the degree of expansion of the sand bed in filter washing and emphasized the higher efficiency of the more viscous low temperature water, in expanding the media, the authors became interested in the importance of wash water control to secure effective bed expansion under all conditions. To this end Krum, in cooperation with the Simplex Valve and Meter Co., developed the sand expansion indicator, now used successfully in many plants. Data on these studies was first published in WATER WORKS AND SEWERAGE.[5]

For the Allentown experiments a model filter unit with glass sides was constructed. It had an effective area of one square foot and was built to full vertical scale. It was equipped with the perforated concrete Leopold bottom, a duplicate of the block originally installed in the Allentown plant. In other words, the experimental unit is an exact replica of a 12-inch square section of the full size filters.

Sand for the experimental unit was taken from one of the plant filters, using a perpendicular column of sand extending from the surface down to the gravel layer. The sand at the bottom of this column had the appearance of clean sand, but the top 8 inches was black in color and had a coating of impurities, approximating 20 per cent by weight. This experimental bed was washed repeatedly, probably 200 or 300 times, at wash rates which expanded the sand in varying degrees up to 60 per cent.

During the course of these experiments on the rate of expansion no new sand was added to the filter; nor, although the unit is equipped to receive coagulated and settled water, was such water applied to the unit. The coated condition of the top sand at the end of the repeated high rate washings in these experiments has the appearance of a layer of black water rather than sand.

At the conclusion of these expansion experiments a fixed jet surface wash of the Baylis type, a perpendicular pipe extending downward and ending 3 inches above the top of sand bed, was installed in the experimental filter to determine whether or not the coating on the sand grains could be removed by this method of washing. The results were startling. The application of the high pressure water jets to the unexpanded sand created a violent movement in the top 8 inches of the bed. This scoured the sand so effectively that the supernatant water immediately became opaque because of the turbidity, and was black in color. After two minutes of this initial scouring of the settled bed, wash water was introduced from below and the entire bed of sand expanded 50 per cent. The resulting downward movement of the upper sand, due to the action of the surface jets, and contact with the upward movement of the lower sand due to the back wash, caused a second violent scouring, with a penetration to 18 inches below the surface. Repeated washing of the sand in the experimental unit by this method resulted in the disappearance of the black coating on the top sand, and the entire volume of sand attained the appearance of uniformly clean sand.

This demonstration convinced the authors of the comparative inefficiency of the normal method of washing filters. Observations, in other plants have simply confirmed this conviction and further convinced us of the comparative inefficiency of the normal method of washing filters.

Full Plant Scale Data

The Allentown filter plant was built in 1928 and takes water from the Little Lehigh River, a stream draining a fertile farming area, with consequently widely varying turbidities. The works comprise an intake well with screens, low lift pumps, a baffled mixing basin, with an actual retention period of about 20 minutes for floc formation, duplicate sedimentation basins of about 2 hours capacity, and 8 rectangular filter units with a capacity of 1.25 m.g.d. each. Alum is used as a coagulant, with pre- and post-chlorination. The only unusual features of the plant are the nonmetallic Leopold Duplex Filter Bottoms. The raw water alkalinity is above normal for Pennsylvania and somewhat hard, but is not grossly contaminated. Some few industrial wastes in minor quantities are present in the water.

The history of the Allentown filter units is typical of many other plants, with probably an average amount of mud ball formation, some gravel disturbance, and an occasional hard spot at the outer perimeter of the units and in the corners. Since the plant was built in 1928 the sand has been ejected from the filters twice for the purpose of breaking up mud balls and to examine the condition of the gravel layers.

Conditions at Allentown, the authors feel, average the field quite generally except for the absence of troubles commonly due to metallic bottoms. The plant is operated at full rates with daily shutdowns of several hours each day.

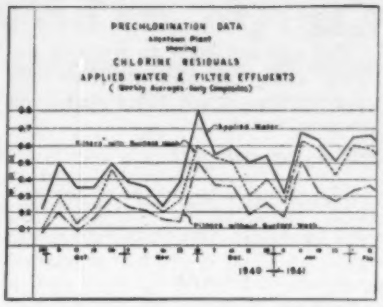
After due consideration of the condition of the filters and other factors involved, and because of the results observed in the experimental filter, a rotating Palmer Filter Bed Agitator was installed in filter No. 3 in April, 1940. The results were so satisfactory, from a visual standpoint, that four additional filters were equipped with Palmer Agitators, the first being installed in July, 1940, and the last two in April, 1941. The remaining three filters in the plant are likewise to be equipped before the end of 1941.

The surface dimensions of the Allentown filters are 20 feet by 22 feet. The Palmer Agitator installed consists of one brass unit with properly placed jets and with an overall length of 19½ feet, the longest arm used anywhere, according to the manufacturer, up to the time of the last installation. In order to provide rigidity for the agitator, sections of galvanized pipe 2½ inches in diameter in the form of a cross are fastened to the four walls of the filter with wall flanges.

Mud Ball and Coating Reductions

Before the second installation was completed in August, 1940 (filter No. 4), samples of sand were taken from the top 6 inches of the bed and the volume of mud balls accurately measured, using the method advocated by Baylis.* In addition, the amount of coating on the sand grains was determined by treating a weighed sample with concentrated hydrochloric acid, washed, dried and reweighed.†

These determinations have been repeated monthly since that time. It will be noted in Table 1 and Graph 1 that the average amount of mud balls in the top 6 inches of the seven filters not equipped with agitators was 5.6 per cent. In filters No. 3 and 4, equipped with agitators, after one month of service practically no mud balls remained.



Graph 3—Chlorine Removal by Filters
Contrasts chlorine absorption by coated sand vs. clean sand in filters equipped with Palmer agitators—an index of sand cleanliness and operating economy.

Table No. I

Filter	% Mud Balls	—Sand Characteristics— Eff. Size	Uniformity Coef.
No. 1	4.3	.63	1.35
No. 2	4.6	.53	1.32
No. 3	0*	.60	1.50
No. 4	7.2	.53	1.40
No. 5	8.3	.55	1.36
No. 6	6.0	.55	1.36
No. 7	2.9	.54	1.40
No. 8	6.1	.69	1.30

*Not tested previous to installation of Palmer agitator. Tests—October 29, 1940.

Unfortunately, no sand coating test was made on the sand in filter No. 3 prior to the installation of the agitator. However, the average coating on the sand in filters No. 4, 5 and 6 before the installation of the agitators was 23.4 per cent. The rate of reduction in sand coating, as the result of surface scouring, is shown in Graph 1, which tells its own story better than can be told in many words.

Wash Water Savings

The authors are unable to confirm claims made by others as to marked savings in wash water through the use of surface wash, either by careful analysis of the Allentown plant data or after more general observations elsewhere. It is conceded, however, that other operators may have collected information demonstrating success in this phase of the operations where filter design may not have been as satisfactory—as at Allentown.

At Allentown it has been the practice to wash each filter unit at a loss of head of 6 feet, or immediately upon the appearance of turbidity in the effluent of such filter, rather than to depend entirely on the loss-of-head rate-of-flow, or time period, as variously and generally practiced. Successful coagulation and sedimentation, as well as the turbidity of the raw water, under Allentown procedure greatly affect the length of filter runs. Data on filter runs at the Allentown plant for the year 1940 are shown in Graph No. 2. The effect of spring and fall rains is reflected in the shorter runs in April and November.

In a study of these filter run figures, consideration should be given to the fact that the sand in the plant has been in use for 12 years, and that considerable variation exists in the sizes and uniformity coefficients in the various units because of the gradual and non-uniform loss of the finer particles. The possible effects of these sand characteristics has not as yet been studied in detail.

An examination of the graph on filter runs reveal no definite trend in filter run time, nor does it indicate any reasons for a failure to secure longer runs. The general average of the agitator-equipped filters is approximately that of the other units. The high percentage of wash water used for filters No. 3 and No. 4 in the first months after installation of the agitators in these units, undoubtedly was due to frequent washing for demonstration and experiments, rather than to normal procedure.

From the standpoint of increased length of filter runs, therefore, no savings in wash water have been secured at Allentown. The same general impression seems to have been arrived at in other plants under observation, without any definite figures available for confirmation. A lower sand expansion index has been used at Allentown in the agitator-equipped units than in those not so equipped, but the saving in wash water which apparently should be effected has not been confirmed by actual measurement and plant data.

At Allentown, as previously stated, prechlorination is a regular practice. One of the gains effected through the surface wash installations and a further indication of the increased cleanliness of the media in the units so equipped has been the greater residual chlorine maintained in the effluents of these filters, as compared with the effluents of the remaining filters. Data are shown in Graph 3.

Chlorine Economy

It will be noted that the chlorine residuals in the effluents are uniformly and consistently greater for agitator equipped units No. 3, 4 and 6 than for the other units not so equipped. On many occasions the residual of these units has shown very little reduction from that of the residual of the applied water. In actual practice this means eventually a decrease of appreciable amount in the rate of application of pre-chlorine, with subsequent savings in expenditure for this chemical when all filters have

been equipped with surface wash facilities.

This effect of the cleaner sand on chlorine residuals (chlorine absorption by the bed) was first noted in December, 1940, some six months after the first agitator was installed in filter No. 3 and three months after No. 4. Detailed studies and observations on the residuals of the separate units was then begun and have since been continued.

The heavy chlorine demand of the average filter unit is well known, and it is sometimes difficult to secure any residual chlorine through a filter bed unless the sand is super-chlorinated before pre-chlorination is begun, or until heavy pre-chlorination has been practiced for some considerable period of time. As a matter of fact, many an operator has been brought to grief through the application of pre-chlorine to dirty filters because of subsequent severe taste and odor production resulting from reactions between the chlorine and accumulations within the ineffectively washed sand bed.

At Allentown all filters were thoroughly chlorinated before pre-chlorination was begun. Prior to the time the first agitator was installed, application of chlorine in doses up to 1.14 lbs. per million gallons had been used continuously for approximately 12 months, with the point of application at the influent of the mixing chamber, approximately three hours before the chlorinated water reached the filters.

The decreased chlorine demand of the filtering media after the agitators were installed became apparent almost immediately in filter No. 6, and after about two months of operation, the residual of this unit reached approximately the same figures as for those of filters No. 3 and 4, which had been surface washed for about 6 months and 4 months, respectively, prior thereto.

The authors hope to make a detailed study of this problem—the chlorine demand of filter media—in the near future.

Costs of Installation

The effective apparatus of the agitators, consisting of a toggle joint, pipe manifold, and special nozzle openings, all of brass, was purchased at a cost of $197.64 for each unit at Allentown. Auxiliary valves and pipings were purchased by the city and installed by the salaried employes of the city. Basing the labor costs, however, on current hourly rates for skilled mechanics, and adding in the costs of piping, valves, etc., the total cost of installation for one unit (1.25 m.g.d.) was $310. This would mean a total cost of about $2,500 to equip all eight filters in the plant.

In this cost analysis, consideration must be given to the fact that the Allentown filter boxes are almost square in plan (20 by 22 feet), so that it was possible to use only one revolving mechanism to each unit. With filters of dissimilar area, the costs may be greater because of the necessity for installing two or more arms in each bed to cover the entire area. Apparently a reasonable average cost figure, for general use, might be given as $350 per M.G.D. of filter capacity.

Summary

1. To a greater or lesser degree, mud balls and hard spots are common to rapid sand filter units.

2. Despite careful design, careful operation, and a multitude of practices, no generally successful method of preventing these disturbances had been found prior to the development of the surface wash by Baylis about 1930.

3. In all plants where surface wash has been made an auxiliary to normal bottom wash, improvements in the appearance and cleanliness of filter media have been made.

4. Surface wash piping or the revolving Palmer agitator can be installed without any major interference with normal filter operation.

5. Costs of installation of the Palmer Agitator depends on the size and shape of the filter boxes, but generally speaking, should average about $350 per M.G.D. capacity, including all costs for labor and appurtenances.

6. At Allentown, Pa., with a Palmer Agitator to provide surface wash:

a. Mud balls were practically eliminated in five weeks' operation of a full scale unit.

b. Coating on sand grains was materially reduced.

c. No appreciable saving in wash water has resulted through the use of surface agitation.

d. With pre-chlorination, the effluent of agitator equipped filter units show continuously higher chlorine residuals than do the units washed at high rates but without surface agitation.

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Dry Feed Dosages in Grains Per Gallon Converted to Ounces Per Minute

Grains Per Gallon	Weight in Ounces Per Minute — Rate in Gallons Per Minute									
	50	100	150	200	250	300	350	400	450	500
0.1	0.0114	0.0228	0.0342	0.0457	0.0571	0.0685	0.0799	0.0914	0.1028	0.1142
0.5	0.0571	0.1143	0.1714	0.2285	0.2857	0.3428	0.3999	0.4561	0.5142	5.7140
1.0	0.1142	0 2285	0 3428	0.4571	0.5714	0.6856	0.7999	0.9142	1.0285	1.1428
2.0	0.2285	0.4571	0.6856	0.9142	1.1428	1.3713	1.5999	1.8284	2.0570	2.2856
3.0	0.3428	0 6856	1.0285	1.3713	1.7142	2.0570	2.3998	2.7427	3.0855	3.4284
4.0	0.4571	0.9142	1.3713	1.8284	2.2856	2.7427	3.1990	3.6570	4.1141	4.5712
5.0	0.5714	1.1428	1.7142	2 2856	2.8570	3.4284	3.9997	4.5712	5.1426	5.7140

$$\text{Ounces per minute} = \frac{\text{Dosage in g. p. g. x Rate in g. p. m.}}{437.5}$$

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Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

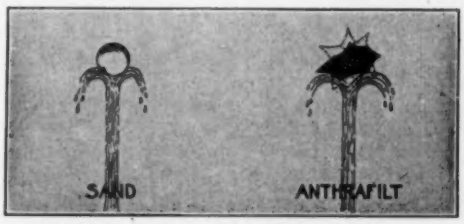
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effective size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sises. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

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No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

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Practical Methods of Metering

By E. H. RUEHL
Stuart Royer & Assoc., Engrs., Richmond, Va.

THERE are many good reasons why water service should be metered, a few of which are:

1. It is the fairest way of selling water, as all customers pay in proportion to their respective consumptions.

2. The water department or company has a pretty good check on the amount of water sold and by comparison with readings of a master meter can better establish losses and leakage and thereby reduce waste in the system in general.

3. Leaks in consumers' service lines can better be located.

4. Knowledge of the various water consumptions is essential in establishing water rates, and the only way in which this information can be obtained and analyzed is by metering of all services.

In some cases, especially in the municipally-owned plants, there are certain institutions, such as schools, hospitals and the like, that are supplied with water without charge, and these should be metered and read regularly to get the full benefits of 100 per cent metering.

And here let me digress a little to state that the words "municipally owned" are generally a misnomer, as in the majority of cases the municipality has a large obligation in the form of outstanding bonds, and the only part that is really municipally owned is the amount covered by bonds purchased back, or some such similar item. This is mentioned here because in the municipally operated plants we are so often confronted with the statement that the people own the plant and for this reason they should have all the water wanted for some flat rate that is nowhere commensurate with the cost of producing the water, the fixed charges being lost sight of entirely.

5. It has been proven that as meters are installed that consumers' water wastes have been reduced and this in turn effects economies in the amount of power required to pump, if it be a pumping plant, and in treatment costs, which are getting higher and higher every day.

6. As the water requirements of the city are kept within bounds and more or less controlled, the size of the treating and pumping plants and storage and distribution systems are kept to a minimum, thereby keeping capital investments to a minimum, as well as the necessary interest and sinking fund charges which all result in keeping of the water rates at the lowest possible figure.

7. As the time has come when sewage treatment will become necessary in a good many places, the lowering of the water losses and wastes will redound to the town's advantage in requiring a plant of smaller capacity than would be necessary if water usage and wastage were uncontrolled. Likewise, sewage pumping costs will be less.

Mr. Ruehl is a former City Manager of Bluefield, Va.

Ownership and Location of Meters

The ownership and location of the water meter are two subjects on which divergence of opinion exists. In the writer's opinion, the meter should be owned by the water department or company (being charged to capital account) and all maintenance should be done by the owners and charged to operating costs. In Virginia the meter setting just inside the curb line offers so many advantages over other locations that these readily outweigh any disadvantages in the nature of a small additional installation cost, should this be the case. In a good many houses in this section of the country there are no basements in which to locate a meter.

Advantages of Outside Setting

The advantages of outside setting, located in the sidewalk space, are in general as follows:

1. Meter reading is greatly facilitated due to the fact that the reader never needs to wait for a response from the householder on knocking, and does not have to make a second trip if absence of the occupant prevents a reading on the first call. The distance the meter readers have to walk is lessened when outside settings are used, and this in turn permits more meters to be read per day.

2. The meter is always accessible to water department employees for reading, inspecting, testing and repairing.

3. The danger of the meter readers and other water department employees from attacks from vicious dogs is eliminated.

4. The chance of unauthorized persons entering the house in the guise of water works employees is greatly eliminated.

5. Chance of the meter being covered by rubbish, coal, kindling wood, etc., is done away with when the outside setting is used.

6. More accurate reading can be procured when outside settings are used because of better lighting outside than generally exists in basements, under porches or other places where meters might be set.

7. The line of separation between the water department and property owners' liability is clearly defined and there is not much chance of unauthorized connections being made behind the meter.

8. In case of necessity of cutting off the water for non-payment of bills there can be no dispute as to entering the premises if the meter and control are located at the curb line.

9. The outside setting should be in a locked box. As it is below the ground, it is not so apt to be tampered with as would a setting in a more conspicuous place not protected by a box.

10. Less danger of damage to the meter by hot water exists if set at the curb.

11. Danger from freezing is practically eliminated in a well set meter, and in case of fire in the building supplied the meter is not in danger of being destroyed.

In view of all these reasons the writer is of the opinion that the entire meter setting, including the necessary cut-off valve, should be located in the sidewalk space behind the curb line, and that the water department's or company's maintenance and obligations should stop at the customer's side of the meter.

Type of Setting

The following remarks apply to the smaller size meter up to 1 inch, and when larger sizes than this are used the condition must be studied separately and settings made to suit.

It is realized that a properly set meter, although not always the cheapest, will receive more attention in general from the water works operatives and in turn pay higher returns to the department.

It is a good plan to set the meter in a yoke with at least a control valve at the inlet side, although some prefer

valves at both the inlet and outlet sides. This does away with the customary curb stop and box.

The meter in its yoke, and with the control valve, should be set in an earthenware, concrete or iron box with sufficient clearance between the risers, if they be used, that the cold ground outside cannot cause the water in the pipes or meter to freeze. A type of box that has proven very satisfactory in our section of the country is one 18 inches in diameter and 24 inches deep, with side slots at the lower end to accommodate the varying depths of the service pipe. The latter, we feel, should be about 24 inches below the ground.

It is important that a lid be provided that fits the top of the box tightly, preferably being locked on with some kind of a locking device. If the lid is fastened on there will be no circulation of air in the box and consequently less danger from freezing. Another advantage is that if the lid is kept on tightly there is less danger of persons tampering with the meter or of pedestrians catching their feet in the hole, with a possible damage suit resulting.

It is also very important that the bottom of the box extend below the maximum frost line so that the warm air from below can rise up around the meter and risers and keep the atmosphere in the box above freezing. In extreme cases it has been found that a smaller tile pipe about 8 inches in diameter put vertically into the ground below the bottom of the regular box (to reach warmer levels) overcame freezing troubles by admitting warmth from below.

Meter Reading

In the writer's opinion, meters should be read monthly, if this is possible, as by so doing a closer touch is kept on losses and wastes, and due to the visiting of each meter every thirty days the stopped meter and other irregularities can be more effectively dealt with. In case a customer has a leak he can be notified within a reasonable time if the meters are read monthly, but if they are read, say, quarterly, the amount of leakage passed will more likely be an appreciable amount and cause some disagreeableness when an attempt is made to collect the bill.

Experiences at Bluefield, Virginia

If you will pardon personal experiences, it may be of some interest to tell how the town of Bluefield recently attacked the problem of setting 700 meters at the rate of something like 100 per week. This was carried on as follows:

A work sketch was first made up and the various kinds of equipment decided on. After the meters, yokes, boxes and covers were ordered out, some figures were made up giving the length of pipe to be cut from the service to allow for elbows, yoke valve, etc., and the vertical distance that cover, meter, yoke and fittings required was figured and each made into a constant.

Actual installation started with several men digging holes, located from the curb boxes whenever possible, in a certain well-defined section so that one foreman could keep all things going. Two men, both of whom had some previous pipe fitting experience, were formed into a "gang" and given instructions how to set the meters, and they then worked together for about a day. These men then were given a helper each and two setting "gangs" were formed and these two helpers were in turn given helpers and four setting "gangs" were formed in a few days. The work was carried through, with as many men as were necessary to prepare the holes ahead of them.

Tools Required

Each of these setting gangs of two men each was furnished with a ratchet die holder and one-half and three-quarter inch dies, a hack saw, two 10-inch Stillson wrenches, a pipe vise attached to a four-legged board, a homemade wooden straightedge, and a pair of hip boots. The men provided their own rules. The meters, yokes, boxes, covers, pipe, etc., were supplied to the location by a Ford truck. Galvanized nipples of various lengths were purchased and used wherever possible, as they could be purchased cheaper than we could buy, cut and thread the pipe.

When the hole was opened down to the service pipe the meter-setting gang (two men) came along and the first thing they did was to lay the straightedge across the hole and measure down to the service pipe, and from this the proper "constant," referred to above, was subtracted, which gave the length of risers necessary to bring the top of the meter to the desired point below the meter box lid. If there was a standard nipple of length somewhere near this dimension it was used. If not, the helper would cut pipe to the proper length and thread it. The meter setter in the meanwhile would be cutting a piece of pipe of predetermined length out of the service line and threading the cut ends for elbows. The risers were then screwed in and the yoke and meter set, after which the box was put in the hole. By using a set of specially made hooks the box was easily adjusted around the meter and risers, and the cover put on.

Two men constituted the back filling gang and followed up all setting gangs, backfilling all holes and seeing that the lids were properly fastened.

If the existing cut-off in the service line was so located that it could be used to control the water, it was used, but if not, the meter setter would cut and thread the pipe under pressure, which only took a very few minutes. He would screw the riser pipe with control valve on, bail out the hole, and go on without having to dig back to the main or cut the water off of a section of the town. The water lost amounted to very little.

One foreman looked after the entire job and 700 meters were set at the rate of about 100 per week.

The cost of this work complete, including tools, boots, and everything, was slightly under $19 per setting, which also included the changing of some services where it was necessary.

We believe that in a place where the services are fairly close together one foreman could handle about six meter setting gangs with the necessary hole diggers and could set about 150 meters per week, providing that everything is thoroughly planned ahead.

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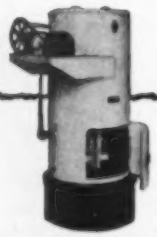

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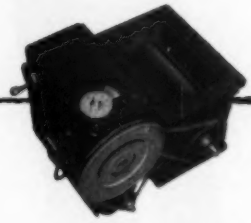

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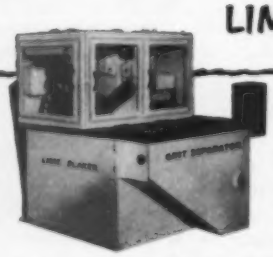

Continuous operation . . . available with capacities from 50 lbs./hr. to 10,000 lbs./hr. Rapid, thorough slaking . . maintains high slaking temperature. Furnished with Gravimetric or Volumetric Feeders. Bulletin 40.20.

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BIF METERS FEEDERS CONTROLS

Guides for Selecting Chemical Feeders

By PAUL A. COFFMAN, JR.
Chief Engr., Omega Machine Co., Providence, R.I.

AT some time in his career, nearly every waterworks operator is faced with the problem of designing a chemical feeder installation, and of selecting and purchasing the equipment. The final success of the feeder installation depends largely upon the thought and study given to the problem before equipment is purchased.

The science of handling and proportioning chemicals for water treatment has advanced to the point where standard equipment is available from several manufacturers for solving practically any feeding problem. The choice or selection of chemical feeding equipment to fit a particular situation likewise can be standardized within certain limits, and it has been possible to develop guides for the selection of this equipment.

Once the water treatment process to be used has been decided on with competent technical advice from the consultant, it is time to select chemical feeding equipment. Such advice should include a decision as to the chemical to be used, whether it will be fed in dry or liquid form, the point of application, and due consideration of availability, cost, quantities to be handled, solubility and stability of the chemicals which can be used.

This paper deals with guides for the selection of dry chemical feeding equipment. A future paper will deal with liquid feeding equipment. There are eight principal guides for selecting dry chemical feeding equipment.

Guides for Selecting Dry Chemical Feeding Equipment

1. Define
Operational Requirements

2. Determine
Storage Capacity Required

3. Choose
Best Available Location

4. Choose
Type of Installation

5. Choose
Type of Feeder Preferred

6. Select
Accessories Desired

7. Furnish
Information for Manufacturers

8. Evaluate
Proposals Submitted

Guide No. 1— Define Operational Requirements

1. Determine the feed rate requirements for the installation. It is important to give careful consideration to the actual maximum and minimum rates of feed required. If minimum and maximum rates required are not carefully determined, equipment manufacturers may be forced to offer larger or more expensive equipment than is actually needed for the job.

2. Decide on the degree of accuracy required. If the process is critical and chemical feeding must be precise, a per cent plus or minus tolerance is probably all that can be allowed and gravimetric feeders must be used. On the other hand, if the chemical treatment required can vary some, without seriously affecting the process and a considerable retention period is available for ironing out variation in dosage, then a feeding accuracy varying from three to five per cent from the selected feed rates may be satisfactory, and volumetric feeders can be used.

3. Decide on the records which will be required for this process. If it is desirable to have totalizers and recorders, then gravimetric feeders should be specified. A log sheet record can be had with volumetric feeders provided they are installed on platform scales. If no scales are furnished, then the only reliable record will be an accurate count of bags of material used on a daily basis. For very low feed rate installations, the bag count method will not be satisfactory because only one or two bags of chemical will be used in a twenty-four hour period.

4. Decide on the type of controls required for the installation. This includes a decision on whether the equipment will be manually controlled or automatic. If the rate of flow through the water plant varies considerably, then proportional pacing may be required. If the feeder installation is for a well station, automatic start-stop control in parallel with pumps may be desirable. For some installations where the feeder is to be in-

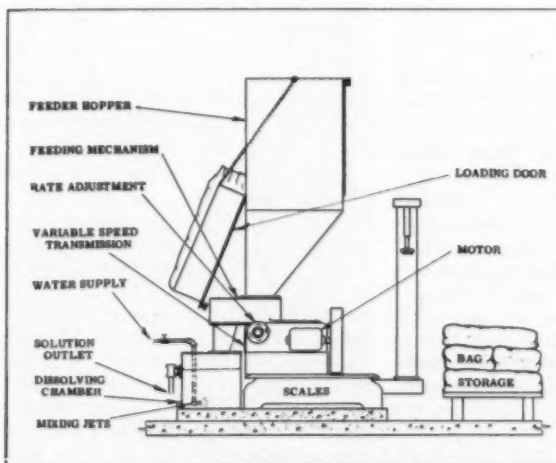


Fig. 1—Small unit feeder installation
Low feed rate—small chemical storage.

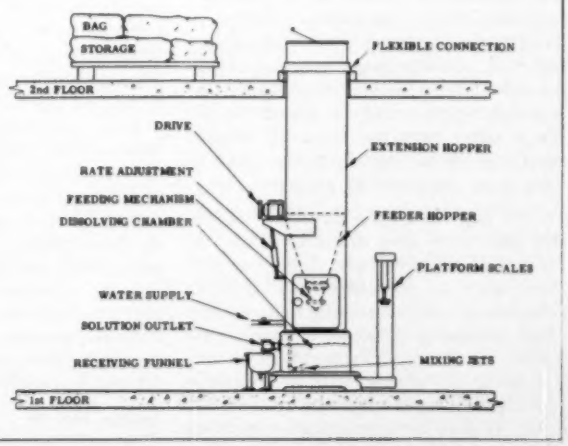


Fig. 2—Two floor feeder installation
Low or high feed rate—second floor chemical storage.

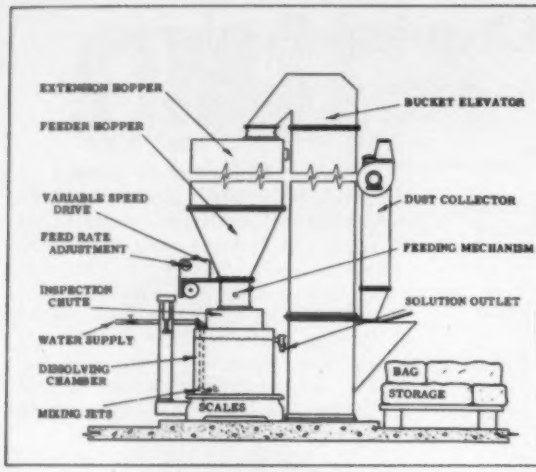


Fig. 3—Mechanical loading installation
High feed rate—large hopper capacity.

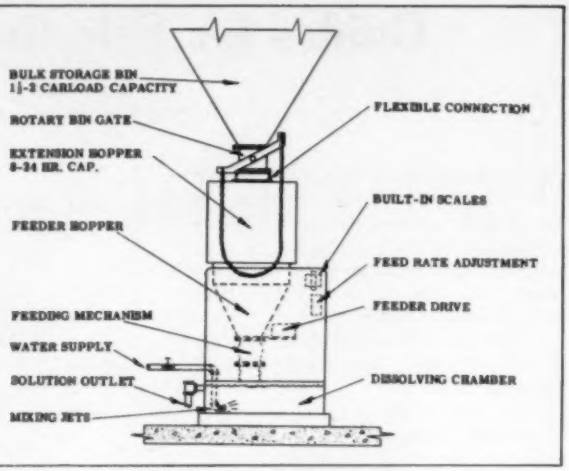


Fig. 4—Bulk storage feeder installation
Low or high feed rate—storage in overhead bins.

stalled in a rather isolated location or where manpower is limited, remote control of the feeding equipment may be an economic necessity.

Guide No. II
Determine Storage Capacity Required

1. Storage in a chemical feeder installation is an important consideration from the standpoint of labor saving and purchase of chemicals in economical quantities. All feeders should have an initial hopper capacity, equivalent to not less than four nor more than twenty-four hour storage when feeding at the maximum required rate of feed. If manpower for dumping chemicals is available on all three shifts, then four to eight hours capacity will be satisfactory; otherwise, provide capacity for twenty-four hour operation.

2. Bag or bulk storage capacity must be determined on the basis of economical purchase and transportation quantities, and time required for delivery from suppliers. Sixty to ninety days' supply is the usual bag or bulk storage requirement. If the chemical is to be stored in bags, due consideration must be given to the floor space required for such storage and means for handling the bags in the most economical manner.

All bag chemicals should be stored on pallets to keep them dry and the chemical storage space should be well ventilated to prevent chemicals from absorbing moisture during storage and becoming difficult, if not impossible, to feed satisfactorily in dry feeders. If more than a few bags of chemical per day are to be handled, it may be economical to provide lift trucks for transporting the pallets of bagged chemical from one feeder installation to another.

3. When the chemical is to be stored in bulk, bins must be large enough to hold at least one and one-half times the normal shipping quantity. If the water plant is a great distance from the source of supply, there is a chance of delay in transit and additional storage capacity should be provided, so there will be no danger of the plant running out of chemical between shipments. The usual practice is to provide a minimum of from one and one-half to two carload storage capacity when chemical is purchased in bulk.

Guide No. III
Choose Best Available Location

1. The hydraulics of a chemical feeder installation should be studied very carefully before selection and purchase of equipment and solution lines. Whenever possible, choose a location that will permit the dry chemical to flow entirely by gravity from the storage level to the feeder and dissolving chamber, then by gravity from the solution chamber to the point of application. Such accessories as conveyors, pumps and ejectors should be eliminated if possible.

2. If a location is not available with these ideal conditions, then choose the location that will require as little pump or ejector head as possible. This is particularly important in the feeding of alkaline chemicals when hard water is used in the dissolving chamber. Pumps and ejectors on chemical solution lines always require frequent cleaning and servicing and their use should be avoided whenever possible.

Guide No. IV
Choose Type of Installation

There are four basic types of dry chemical feeder installations:

1. *Small Unit Feeder* (Fig. 1) used when a very low feed rate and small chemical storage capacity is required. The principal parts are: feeder hopper, feeding mechanisms, means for feed rate adjustment, variable speed transmission or equivalent, water supply for mixing jets in dissolving chamber, dissolving chamber sized for adequate detention of the chemical being fed, and platform scales for an accurate check on the performance of the equipment.

2. *Two-floor Installations* (Fig. 2) used for low or high feed rate with bin storage on the second floor. This installation contains the same essential parts as the small unit feeder installation plus an extension hopper for additional storage capacity. This type of installation has the advantage that all chemical is handled in a separate room on the second floor—thus confining to the chemical storage room, dust and dirt incident to handling bagged chemicals. An ideal refinement, highly desirable but not absolutely essential, is a dust collector installed on the extension hopper at the second floor level, to eliminate dust in the chemical storage room while loading the hopper.

3. *Mechanical Loading Installation* (Fig. 3) used when the feed rate is high and large hopper capacity is required with bag storage on the first floor. Here again, the essential parts of the chemical feeder installation are included plus an extension hopper, bucket elevator and dust collector. This type of installation is frequently used when new and larger capacity equipment is installed in an existing chemical building. It is also used for new installations with adequate floor space available on one floor for the equipment and chemical storage. (Considerable savings can sometimes

be realized by eleminating the second floor of the chemical building.)

4. *Bulk Storage Bin Installation* (Fig. 4) used for high or low feed rate requirements where chemical is purchased in bulk, usually truckload or carload quantities, and stored in overhead bins. This type of installation is used mostly by large plants where it is economical to purchase chemicals in carload quantities.

These storage bins are usually constructed of concrete or steel and are an integral part of the building. It is considered good practice to make the lower section of the storage bin of steel so that vibrators, plate-type agitators or other agitating devices can be readily installed. A bin installation can be made suitable for practically any type of chemical feeder by fabrication of the steel hopper action to meet installation requirements. Large storage bin installations should include a large rotary bin gate on the outlet of the bin. Minimum size gate 9 x 15 inches, 12 x 12 inches, or preferably 12 x 24 inches. When small bin gates are used on large bins, packing at the bin outlet can be expected.

If the chemical to be stored is of a non-free-flowing type subject to arching and flooding, means for agitation must be provided to insure a flow of material from the storage bin when required. On installations handling a floodable material, the feeder selected should have a Rotolock feeding mechanism incorporated in it to eliminate the danger of flooding through the feeder.

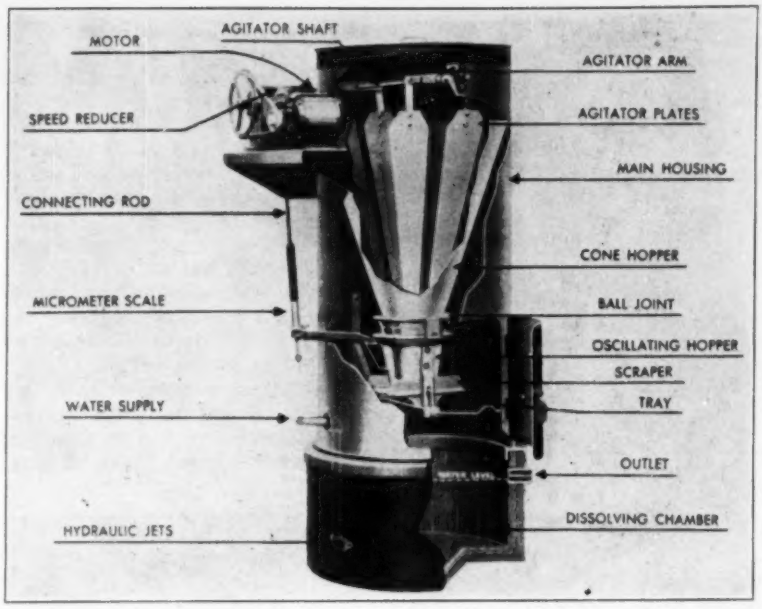


Fig. 5—OMEGA Universal volumetric feeder

Chemical feeder installations under large storage bins should be isolated from the storage bin by means of dust tight flexible connections to prevent damage to the equipment due to expansion and contraction of the large storage bin. The installation shown in Fig. 4 contains all the essential elements of a chemical feeder installation plus the flexible connection, rotary bin gate and bulk storage bin.

Fig. 6—W&T volumetric feeder A-635
With scales for weight checks.

Guide No. V—
Choose Type of Feeder

There are two basic types of feeding mechanisms: volumetric and gravimetric.

When variations of three to five per cent plus or minus (by weight) can be tolerated in the feed rate, and when it is not necessary to accurately record or totalize the actual weight of material fed, then volumetric feeders may be used. When more accurate feed rates (within plus or minus one per cent by weight) are desired and when automatic control of feed rate and accurate records of feed rate are required, then gravimetric feeders may be used.

Volumetric Feeders

Volumetric feeders are designed for volume displacement. They do not incorporate scales in their feeding mechanism. If scales are used they are usually platform scales supporting the entire machine and its contents.

Such scales give a check on the performance of the machine, but do not actually control the rate of feed. Any changes in density or feeding characteristics of the chemical being fed will directly affect the actual weight of material fed. Inasmuch as volumetric feeders measure only the volume displaced and not the weight of the material, it is possible for a volumetric feeder to operate mechanically without feeding any material, and there is no means of warning the operator if material is not being fed. For these reasons volumetric feeders usually require more attention from the operators to insure continuous satisfactory operation of the process.

Volumetric feeders can be used in small plants where:

1. Operation rates are relatively constant.
2. Continuous check on performance of the equipment is possible—for example, regular visits by the operator every half-hour or hour, and checks of the material fed by means of platform scales.
3. Considerable retention capacity in the mixing and settling basins is available to average the minor variations in feed rate due to changes in bulk density or feeding characteristics of the chemical.

Typical volumetric feeders include the Omega Universal, Rotolock, and Disc Feeders; Wallace & Tiernan Series A-635, Type NA and Type A-552; Infilco Type D and Type E; and Syntron Vibratory Feeders.

The Omega Universal Feeder (Fig. 5) is readily adaptable for feeding any of the dry chemicals used in

Fig. 7—INFILCO volumetric feeder Type D
With revolving table.

water plants. The feeding mechanism is the large open oscillating throat type. It is accurate volumetrically and is not readily plugged by lumps or trash. Rate of feed is adjustable over a wide range. These machines are manufactured in three sizes with suitable accessories for any of the four types of installations previously described. The principal advantages of using this type of machine are—low first cost, simple operation, and low maintenance service.

The Wallace & Tiernan Volumetric Feeder, Series A-635 (Fig. 6) incorporates a feeding mechanism of the horizontal screw type utilizing a combination of rotary and axial movement through a feed trough discharging chemicals at both ends. The rate of feed is regulated by a cam operated clutch mechanism by means of a control crank. This machine is primarily offered for unit type installations.

The Wallace & Tiernan Type MA Feeder consists of a slow moving feed roll delivering a ribbon of chemical across the feed apron from which it is fed to point of discharge. Changes of feed rate are made by varying the width of the ribbon and by change gears. The Wallace & Tiernan Type A-552 Feeder has the same type of feeding mechanism as the Series A-635 Feeder.

The Infilco Volumetric Feeder, Type D, (Fig. 7) is a disc-type (revolving table) feeder with position of a feed knife on the disc determining the rate of feed. The Type E machine (Fig. 8) is an extrusion type feeder with a feed pan underlying the hopper and moving with a rocking and reciprocal motion. These machines are primarily used for small unit feeder installations.

The Omega Rotolock Feeder (Fig. 9) is a star wheel or pocket drum type of feeder and is recommended for volumetric feeding of floodable materials such as hydrated lime, activated carbon, clay, etc. The feeding mechanism is entirely enclosed and is driven by an infinitely variable speed transmission (100 to 1 range). It is available with electric or pneumatic rate setting devices for use with automatic pH controllers and proportional pacing systems. Accessories for the Rotolock Feeder are available for all four types of installations.

Omega Disc Feeders (Fig. 1) are used for feeding finely ground materials continuously and accurately at very low rates of feed. When the maximum feed rate required is less than 50 pounds per hour, the Disc Type Feeder should be considered. The feeding disc has a scroll type feeding orifice which provides exact volumetric measurement. Delivery of material is continuous even at very low rates, and directly proportional to the number of revolutions of the disc. An infinitely variable speed drive rotates the disc at the desired speed. Machines with a feeding range as low as one to 25 ounces per hour are available. This machine may be equipped with any of several sizes of feeder hoppers including the loading door hopper, all suitable for hand filling from feeder room floor. This machine is generally used for unit feeder installations requiring low feed rates and small chemical storage capacity.

Fig. 8—INFILCO volumetric feeder Type E
With revolving feed pan.

Gravimetric (Weighing) Feeders:

Gravimetric or weighing feeders are machines designed to feed dry chemicals continuously and accurately by weight. They are to be preferred because of their greater feeding accuracy, wide feeding range, and because automatic controls, alarm devices, totalizers and recorders are readily incorporated into the machine. The rate of feed can be pre-set and the feeder will maintain its set rate of feed by weight regardless of changes in bulk density or flowing characteristics of the chemical being fed. They are easily fitted with accessories for accurate automatic proportional pacing from flow meters.

Gravimetric feeders are manufactured in two types: Belt gravimetric and Loss-In-Weight gravimetric feeders. Typical belt type gravimetric feeders include the Omega Chemizer, the Wallace & Tiernan Merchen Feeder, the Jeffrey Waytrol, and the Syntron belt Gravimetric Feeder.

In the Omega Chemizer (Fig. 10) dry chemical enters the feeder at the top, either from an extension hopper or chute, and passes to the feeding mechanism where it is fed to the scale supported weigh belt which delivers the chemical to the outlet of the feeder. The scale controls the feeding mechanism to maintain a precisely uniform weight of chemical on the weigh belt regardless of changes in density.

Adjustment of the feed rate of the Chemizer may be made in two ways; by setting the counterpoise weight on the scale beam to increase or decrease the weight on the weigh belt and allowing the belt to run at a constant speed; or by the preferred method of

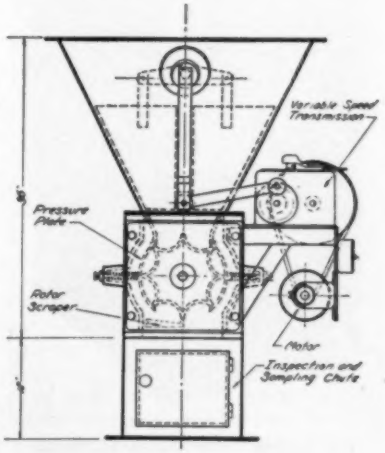


Fig. 9—OMEGA Rotolock feeder

maintaining a constant weight on the belt and varying the belt speed. The scale beam and suspended Omega wedge controls the amplitude of vibrations of the feed tray which delivers chemical to the weigh belt.

When the chemical to be fed is compressible, finely ground and subject to arching and flooding from a storage hopper, a non-flood Rotolock (Fig. 9) is installed above the feed tray in the feeding mechanism.

The Wallace & Tiernon Merchen Feeder (Fig. 11) is of the belt gravimetric type. It incorporates a weigh span between the head and tail rollers of a small conveyor belt, and mercury switches actuated by the scale beam increase or decrease the opening of the feed gate to vary the load on the weigh span. Rate of feed is usually set by adjusting the weight on the scale beam.

The Syntron belt gravimetric feeder (Fig. 12) consists of a short constant speed conveyor belt supported by a small platform scale, and electric vibratory feeding mechanism, and electric or pneumatic controller. Rate of feed is controlled by varying the load on the conveyor belt.

A typical Loss-In-Weight Gravimetric feeder is the Omega Loss-In-Weight feeder (Fig. 13) which, as its name implies, operates on the principle of control of loss-in-weight in the feeder hopper. This machine continuously "weighs out" material from a hopper that is carried on the scales. The rate of feed is determined by the rate that the poise is retracted on the scale beam by a mechanically driven lead screw. Any departure of the beam from exact balance position causes an immediate change in speed of the Rotolock feed mechanism, faster or slower, as required to maintain the scales in balance. The change in speed is affected effortlessly through the Omega wedge control device and the rotatrol mechanism that converts oscillating motion to progressive rotary motion. The Rotolock feeder cannot flood.

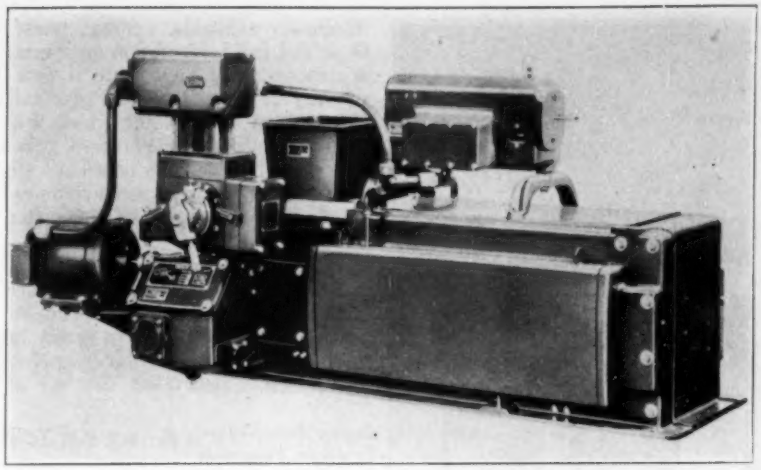


Fig. 11—W&T Merchen belt type gravimetric feeder

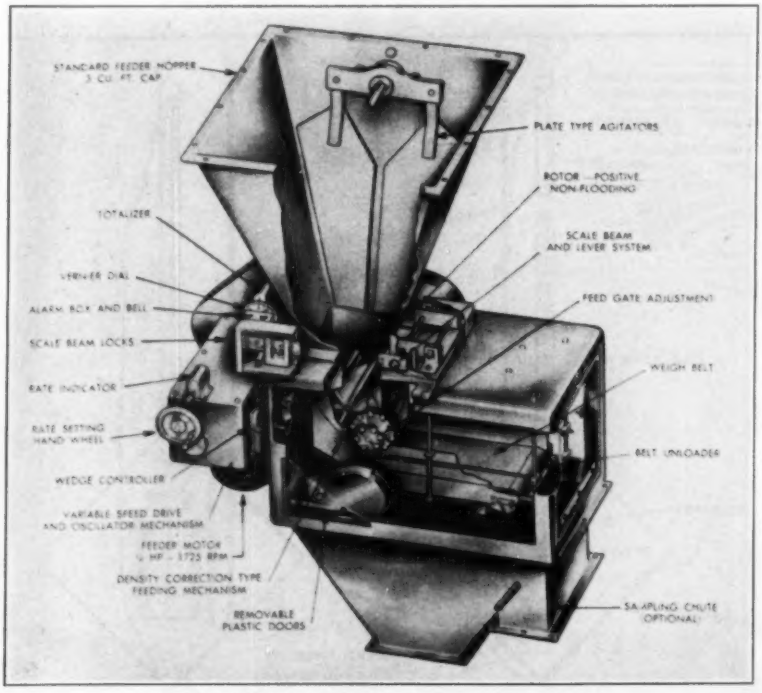


Fig. 10—OMEGA Chemizer belt type gravimetric feeder
With positive non-flood rotor.

Guide No. VI—
Select Accessories For Desired Operations

Practically every chemical feeder installation requires some accessories to satisfactorily accomplish the results required. Such accessories are used at the discretion of the engineer and should be selected on the basis of the actual requirements, making every effort to keep the chemical feeder installation as simple and free from gadgets as possible.

Some of the accessories available are bin level switches, pilot lights, belt shifters, rotary bin gates, remote controls, timers, special electrical starting equipment, control panels, mechanical miners, dust collectors, proportioning weir tanks, dissolvers, and extension hoppers. Accessories such as totalizers, recorders and automatic alarm devices are available on gravimetric feeders only.

There are many other accessories which a chemical feeder manufacturer can usually offer to solve a particular problem.

Guide No. VII—
Furnish Information For Manufacturers

Information that will permit manufacturers to offer satisfactory equipment should include:

1. Chemical and physical properties of the chemical to be fed—name, formula, color, screen analysis, bulk density and any other chemical or physical data available.

2. Type of feeder desired—volumetric or gravimetric, accuracy required (plus or minus 3 to 5 per cent by weight for volumetric feeders, or one per cent by weight for gravimetric feeders); dust removal units, types of controls and accessories desired.

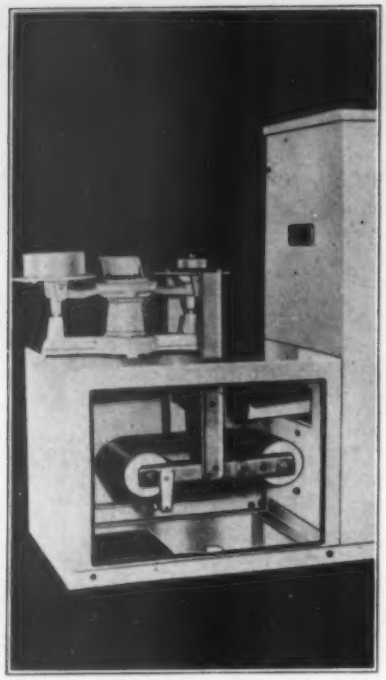


Fig. 12—SYNTRON gravimetric feeder
Belt type.

3. Power available, voltage, phase, cycle and full information on special wiring codes, if any. State if compressed air is available and give full information as to water which will be used including temperature, pressure and hardness if possible. Be sure to mention any special chemical or physical properties of the water to be used.

4. General information—such items as sketches or drawings of space available, indicate bins, hoppers or other equipment existing or to be built which may affect the engineer's recommendations.

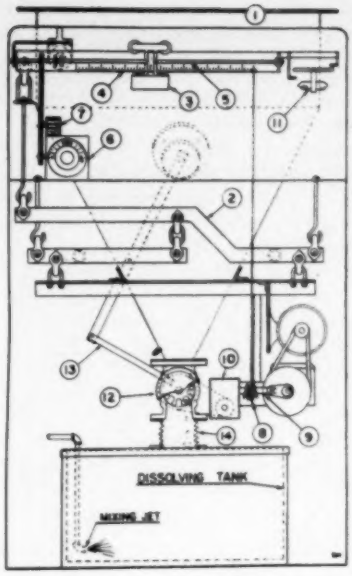
Guide No. VIII—Evaluate Proposals

Give full consideration to these questions:

1. Does the equipment meet the specifications?

2. Will it provide the performance desired?

3. What are the economics of the installation? Consider economics to be not only the first cost, but also cost of maintenance and service, length of life, and cost of operation.



1. Hopper
2. Scale System
3. Poise
4. Scale Beam
5. Lead Screw
6. Lead Screw Drive
7. Totalizer
8. Wedge
9. Oscillator
10. Rotatrol
11. Alarm Switch
12. Rotolock Feeder
13. Agitator Levers
14. Flexible Connection

Fig. 13—OMEGA gravimetric feeder
Loss-In-Weight type.

Apparatus for Collecting Flocculated Samples

THE apparatus shown on the accompanying sketch consists of a wide mouth bottle clamped to a thin board, which in turn is attached to a pole of suitable length. The board is free to rotate on the center pivot and may be turned by the string or light chain attached to the two opposite corners. The bottle may be vented through tubing which extends above the liquid surface.

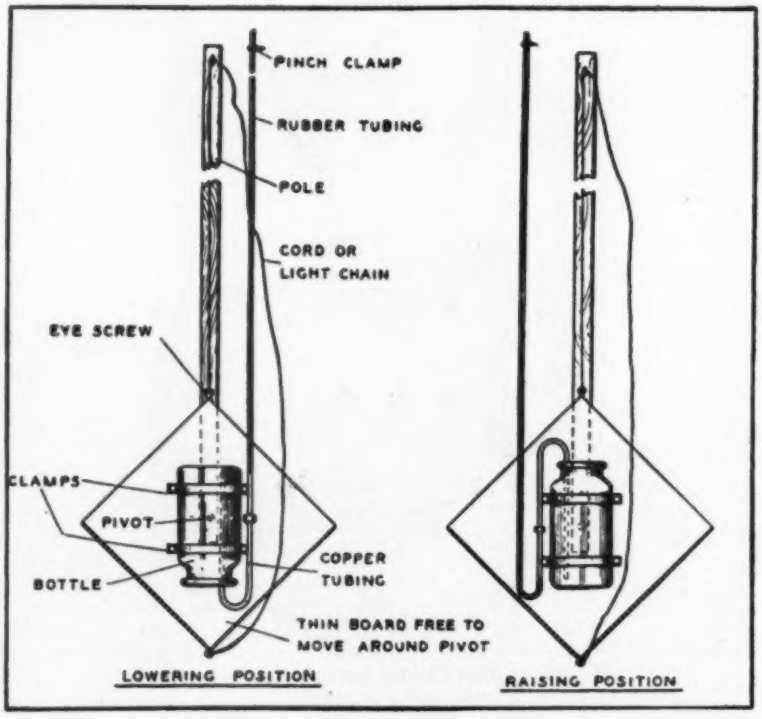
When the bottle is lowered in inverted position, the pinch clamp on the vent line is closed. When the desired sampling level is reached, the pinch clamp is released, so that the floc containing liquid slowly enters the bottle as the air is released. When the bottle is full it is rotated and then raised to upright position with the pull chain.

Through use of this apparatus, flocculated samples from any liquid depth may be collected. The breaking up of flocs, such as occurs when samples are pumped or taken by means of a small mouthed bottle, is avoided.

Acknowledgment

This device employed in studies made by the authors at Ypsilanti, Mich., was perfected by Mr. Geo. Darby, Director of the Westport Laboratories of the Dorr Company. It is a modification of a somewhat similar device earlier developed at the Howard Bend Purification Plant at St. Louis, Mo.

Contributed by A. J. Fischer and A. Hillman, The Dorr Co.



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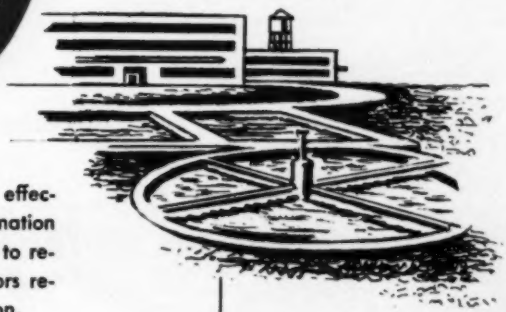

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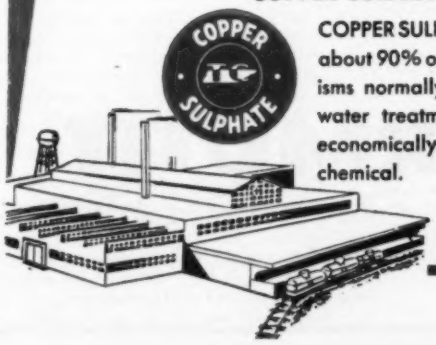

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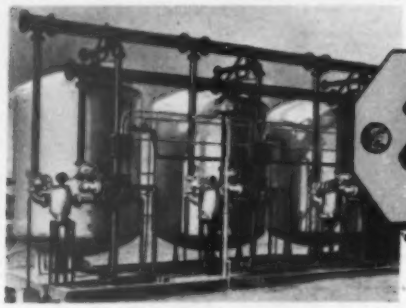

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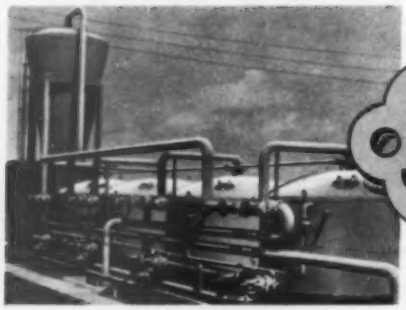

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Iron Removal and Water Softening

By DANIEL J. SAUNDERS
Vice President, The Permutit Co., New York City

IRON and hardness are two of the most troublesome impurities in water supplies; iron because it stains everything with which it comes in contact and hardness because it wastes soap and forms scale. The tolerance for iron in municipal water supplies is usually stated as being 0.3 ppm., expressed as Fe. This concentration is only a very small fraction of the tolerance for hardness in municipal water supplies (i.e., usually 85 ppm. or 5 grains per gallon, expressed as $CaCO_3$).

If the iron content exceeds this 0.3 ppm., staining becomes a serious problem, for then the bathtub, washbowl and other porcelain fixtures no longer present a spotlessly white gleaming appearance but, instead, develop unsightly, rusty brown or even black stains which can usually be removed only by acid. (Parenthetically, it might be remarked that the common practice of having a bottle of muriatic acid at hand for the removal of such stains is not to be recommended especially where children are concerned and oxalic acid is even worse for it is exceedingly poisonous.)

Iron also stains glassware, tiled floors and walls and other materials. As for laundering in an iron bearing water, this presents such an extremely serious staining problem that laundering in a high iron content water is practically an impossibility. Iron also unites with tannic acid to form ink so tea made with an iron bearing water may, depending on the iron content, develop off colors from a grayish to a diluted black muddy appearance. Of course, as everyone who has used such a water knows, if lemon is taken with the tea, it does bleach out the color. Coffee, also, no matter what brand is used, becomes a rather muddy looking and unpalatable liquid. As for the plain drinking water if the iron content is 1 ppm. or over, an unpleasant metallic taste is very noticeable.

In the water supply distribution system, iron deposits tend to form, especially if the water has come in contact with air in a reservoir or storage tank. At times of heavy draft, these deposits are stirred up with the result that the water coming from household taps may temporarily become very muddy. Iron also favors the growth of various iron bacteria, popularly and collectively known as "iron crenothrix" and these growths have a tendency to break loose in clogging masses which frequently develop bad tastes and odors.

Methods of Iron Removal

In clear, deep well, iron bearing waters, the iron is present as soluble ferrous bicarbonate. Iron present in this form may be removed by (1) aeration, settling and filtration, (2) by cation exchangers operating either on the sodium or hydrogen cycle, or (3) if present in amounts of 1 ppm. or less, by manganese zeolite filters.

Iron in an organic or colloidal form may be present in some surface waters, some shallow well waters and an occasional deep well water. Usually such waters have an appreciable content of organic matter and a high color. Organic iron can not be removed successfully by the methods used for the removal of ferrous bicarbonate but can be removed by coagulation with alum, settling and filtration.

Aeration, Settling and Filtration

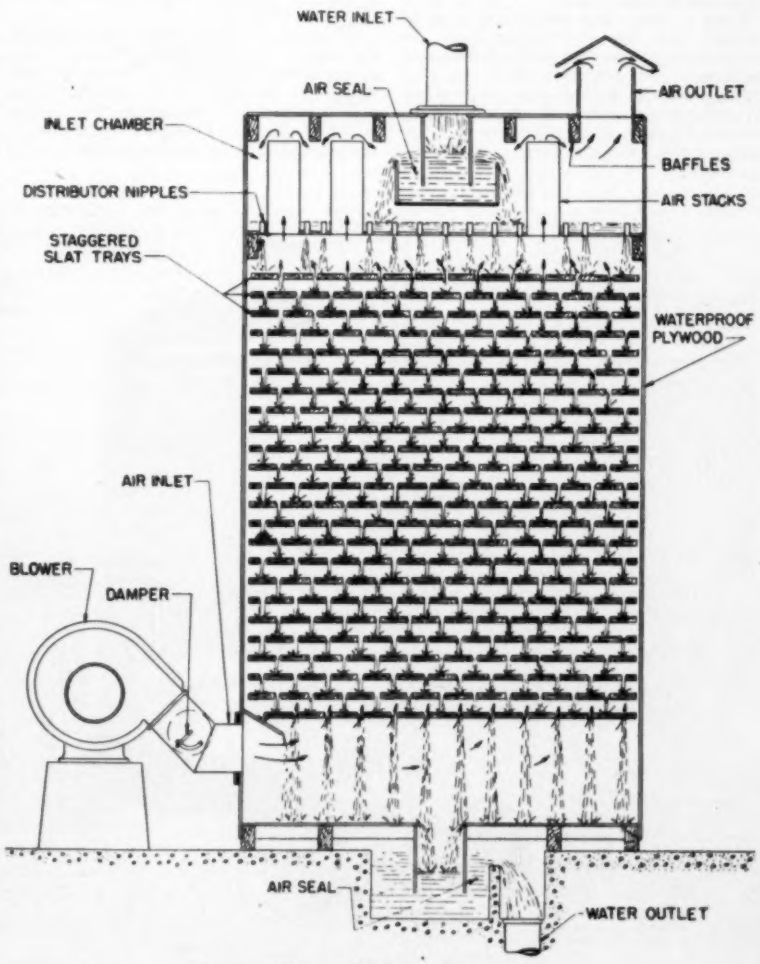
In the first process mentioned above for iron removal, the water is first aerated, which serves both to oxidize the iron and to reduce the content of free carbon dioxide. Certain other oxidizing agents, such as chlorine, may be used, instead of air, but aeration is the process almost universally employed.

Aeration may be carried out in one of several types of open aerators, such as the step aerator, spray aerator, slat aerator, coke aerator, or occasionally, in open basins by blowing air through the water. Also, aeration may be carried out in closed pressure type aerators or aerating filters. In such cases calcite filters may be employed to lower the CO_2 content. Aeration may also be done in a closed type degasifier rectangular in cross-section with one side removable for cleaning.

The oxidizing action of the air converts the soluble ferrous bicarbonate to the practically insoluble ferric hydroxide. With certain waters, this oxidizing action is so slow that it is advisable to speed it up by raising the pH value to approximately 8.2.

As an illustration of the increased speed of oxidation of a ferrous compound at higher pH values, ferrous sulphate, commonly known by the misnomer "copperas," may well be used. Every chemist is familiar with the fact that a solution of ferrous sulphate, which has a low pH value, is fairly stable and that, when exposed to the air, oxidation proceeds at a very slow rate. If such a solution is treated with caustic soda, thus greatly increasing the pH value, oxidation, when air is present, proceeds very rapidly, and insoluble ferric hydroxide is formed.

Similarly in waters of low pH value, containing ferrous bicarbonate, oxidation is slow although, of course, not so slow as



Section Through Rectangular Degasifier (Arrows indicate air flow)

with a solution of ferrous sulphate, which has a very much lower pH value. Therefore, aeration, by reducing the free carbon dioxide content, builds up the pH value and increases the speed of the oxidation. If, in addition, the pH value is increased by an alkali such as hydrated lime or caustic soda, the speed of the oxidation reaction is greatly increased.

The insoluble ferric hydrate produced by this process, may then be removed from the aerated water either by settling or by filtration, or more commonly, by settling followed by filtration. In the latter case, the settling is usually for a comparatively short period, some 15 to 30 minutes.

Filtration is accomplished by the use of sand or anthrafilt filters of either the gravity or pressure type. These are standard filters and as they are operated in the usual manner, no detailed description is necessary. In addition to the usual backwash, surface washers are frequently employed.

Cation Exchange

The removal of ferrous bicarbonate by cation exchange may be accomplished simultaneously with the removal of hardness by cation exchangers operating on either the sodium cycle or the hydrogen cycle. In municipal practice, the sodium cation exchanger process is the one that is almost exclusively used. The cation exchanger may be a green-sand base zeolite, or a carbonaceous or resin type.

When a clear, deep well water is to be softened and also freed from iron, the zeolite water softener may offer the simplest solution to the problem. With most of these waters, the removal is so complete that the iron content of the effluent will usually average 0.1 ppm. or less. In fact, in a few cases, zeolite water softeners have been installed primarily for iron removal, the water softening action being an incidental benefit.

On regeneration with salt, the iron, which has been taken up by the zeolite on the softening run, is liberated as ferrous chloride. This, together with the calcium and magnesium chlorides, is then thoroughly washed to the drain before returning the softener unit to service.

This process will answer for all normal water supplies; for waters of abnormally high iron content aeration, settling and filtration frequently precede zeolite water softeners.

Since the zeolite (or sodium cation exchanger process) yields a water of "zero" hardness, it is customary to by-pass enough hard water to give a mixed effluent with a hardness of about 5 grains per gallon. If the iron content of the raw water is too high to yield a mixed effluent with the desired iron tolerance, the by-pass water should be reendered iron free by separate treatment.

Manganese Zeolite Process

When the iron content is relatively low—1 ppm. or less—and softening is not required, the iron may be removed by means of manganese zeolite filters. The manganese zeolite is a special zeolite manufactured by converting a sodium zeolite to a manganese zeolite by treating it first with manganous chloride and then with potassium permanganate.

In order to remove iron by this process, the water is simply filtered through a bed of the manganese zeolite. This serves both to oxidize the iron to an insoluble form and to remove this product by the filtering action of the bed. These accumulations are removed by periodic backwashings and the oxidizing action is restored by occasional regenerations with potassium permanganate. In this process, only the iron is removed from the water as the manganese zeolite exerts no softening effect.

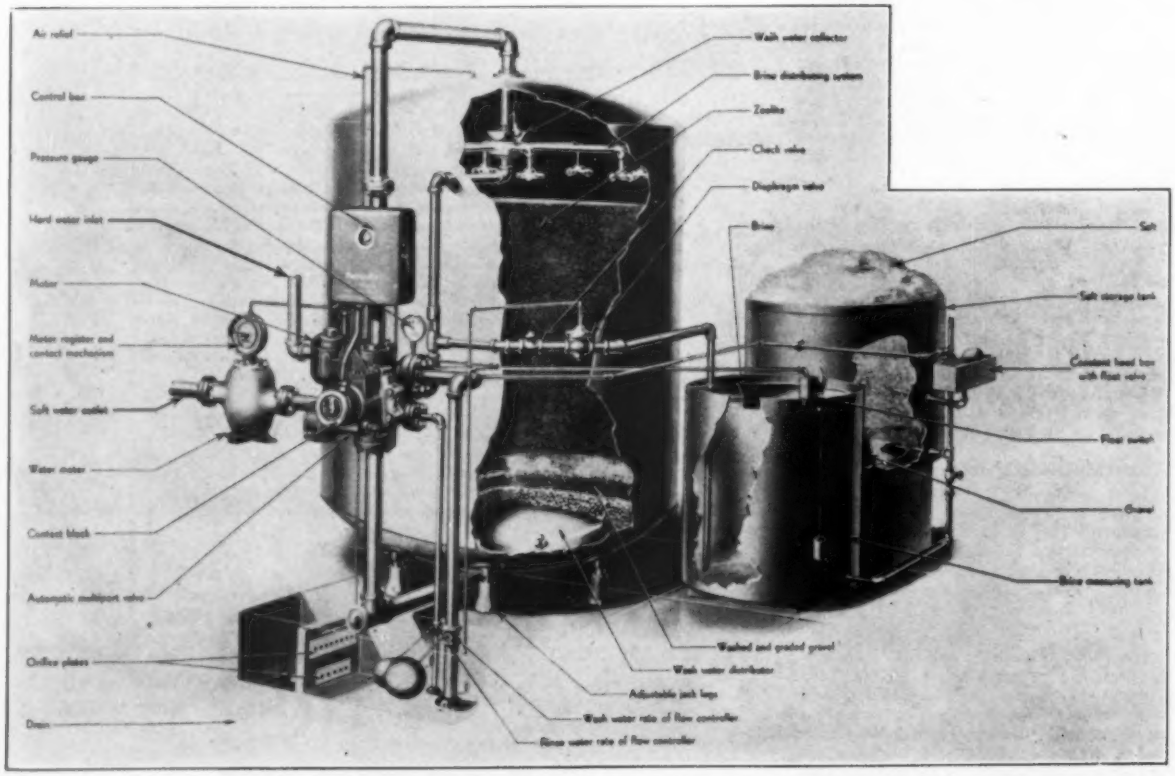
Cold Lime Soda Process

In the cold lime soda (or combination lime zeolite process), ferrous bicarbonate is easily removed with the hardness precipitates by introducing sufficient air into the water to oxidize the iron. If the carbon dioxide content of the raw water is rather low, all that is required is to drop the water, over a couple of steps or baffles, through an air space as it enters the treating tanks. If the water contains a relatively high content of carbon dioxide, then marked economies in the lime dosage may be effected by first passing the raw water through an aerator which may be mounted over the treating tank.

Organic or Colloidal Iron Removal

As previously stated, organic or colloidal iron is not satisfactorily removed by the foregoing processes. Instead it is necessary to coagulate, settle and filter the water. This is not always as simple as it sounds and it usually is necessary to run a series of jar tests to find the optimum conditions, that is, the dosages of coagulant and the pH requirements to secure a good coagulation and the formation of a satisfactory floc. The coagulant which is most widely employed is aluminum sulfate—filter alum—but chlorinated copperas and ferric sulfate are also used.

Chlorination is sometimes of value in removing organic iron but in many cases it seems to have little or no effect. With waters of low mineral content, the use of clay or activated carbon is often of value in aiding floc formation and color removal.



Cut-away of Zeolite Water Softener

Manganese Removal

Manganese, like iron, is an exceedingly troublesome impurity in water but fortunately is much rarer in occurrence. Like iron it may occur as the soluble bicarbonate or in colloidal or organic form. Also its methods of removal are similar, manganous bicarbonate being removed by (1) aeration, settling and filtration, (2) by cation exchangers operating either on the sodium or hydrogen cycle, or (3) by manganese zeolite filters. In removing it by aeration, settling and filtration, however, it is necessary to have a higher pH for its oxidation than is required for iron. In the organic or colloidal form, the method of removal is the same as with iron, that is, by coagulation, settling and filtration.

Municipal Water Softening

Hard waters, as everyone who has used them can well testify, are expensive nuisances. They waste tons of soaps; decrease the life of washable garments; making bathing, shampooing and shaving thoroughly unenjoyable; scale water heaters, boilers, hot water piping and cooking utensils; and increase costs for fuel, labor, repairs and replacements. While these trials and tribulations are recognized by all users, too few realize that it actually costs much less to soften a hard water than to continue using it. Surveys however have proven that, on the average, the costs for the materials used in softening a municipal water supply are only about one-third the cost of the soap wastage incurred in using the hard water.

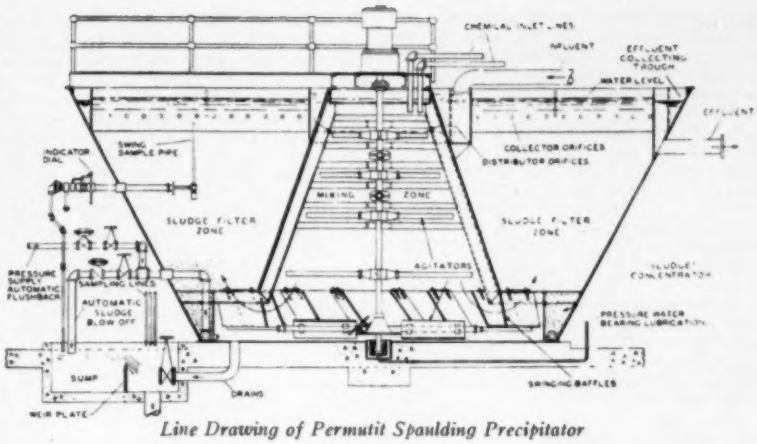
There are three processes which are used in softening municipal water supplies. These are:

1. The zeolite (or sodium cation exchanger) process
2. The cold lime soda process
3. The combination lime-zeolite process

Zeolite (or Sodium Cation Exchanger)

In the zeolite (or sodium cation exchanger) process, the hard water is softened by merely flowing it through a bed composed of a granular sodium zeolite or an organic sodium cation exchanger. This removal of the hardness is so complete that the softened water is usually termed "zero water" meaning a water that is practically zero in hardness. After a definite amount of hardness has been abstracted, the bed is treated with a predetermined amount of common salt brine, which removes the hardness from the bed and restores it to its original sodium condition.

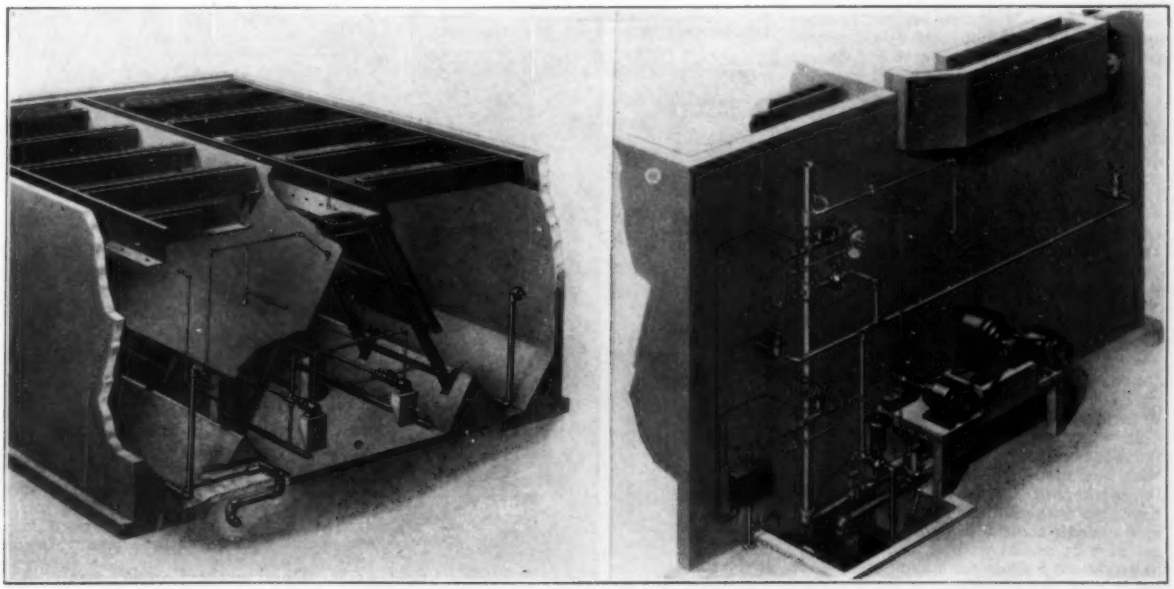
This restoration process is known as "regeneration" and consists of three steps: backwashing, salting and rinsing. The backwashing serves to loosen, cleanse and hydraulically regrade the bed. The salting serves to remove the hardness and simultaneously to restore the bed to its original sodium state. The rinsing serves to remove the excess salt and soluble by-products—calcium and manganesium chlorides—and wash them down the drain. These cycles of softening and regeneration may be repeated indefinitely as the wear and tear on the bed is very slight—usually under 3 per cent per year. Therefore only a slight addition of new material is required annually to keep the bed performing at its full rated capacity.



Line Drawing of Permutit Spaulding Precipitator

The softening plant may consist of a single softener unit or batteries of two or more units. In the latter case the units are usually of such a size that, when one unit is being regenerated, the other unit or units carry the full load. The softener units used in municipal practice may be either of the pressure type or the gravity type. In the pressure type, the bed is enclosed in a steel shell; in the gravity type, the bed is enclosed in a rectangular concrete shell. In both types, the bed is supported by several layers of graded gravel overlying an underdrain system. This serves to collect and pass the softened water to the service lines during the softening run; to distribute the backwash water during the backwashing operation; and to collect and pass to the drain the waste brine and rinse water during the salting and rinsing operations.

Zeolite (or sodium cation exchanger) water softeners are available in fully automatic, semi-automatic or manually operated designs. In the fully automatic pres-



Cut-away View of Horizontal "Precipitator"

Left—Interior; Right—Front Wall

sure type softener, a motor operated valve is usually mounted on the front of the softener unit. In the gravity type softener, a motor operated pilot valve is used to regulate the hydraulically operated gate valves on the softener unit.

In either case, the principles of operation are the same. A water meter on the soft water outlet line is equipped with an electric contact head and an automatic resetting device. At the end of the softening run, a contact is made establishing an electric current which rotates the valve to the wash position. The length of the backwash period is governed by an electric time switch.

At the end of the backwash period, a current is again established which rotates the valve to the brine position. In this position, a predetermined volume of saturated salt brine is admitted to the softener, this volume being governed by an electric float switch. After the brine has been admitted the valve is rotated to the rinse position. The rinsing period is governed by an electric time switch and, at the end of this period, the valve is rotated to the soften position, which again places the softener unit in operation. In the meantime the resetting device on the meter has automatically reset it for the next softening run.

Semi-automatic operation is used principally on waters which may suddenly vary in composition. The semi-automatic units are similar to the fully automatic in operation with the single exception that the regeneration and return to service operations are initiated by the operator instead of by the meter. Manual operation is performed by the operator opening and closing the proper valves in sequence, timing the backwashing and rinsing operations and measuring the drawdown during the salting operation. The valves used may be either of the conventional type or the hydraulic type, the latter being operated from a control table.

In municipal practice, effluents having a hardness of 4 or 5 grains per gallon are usually desired. With the zeolite (or sodium cation exchanger) water softener, such effluents are obtained by softening a portion of the water to "zero" and then mixing with it whatever proportion of hard water is required to reach the desired quality of effluent. If the raw water contains appreciable amounts of iron, it is the usual practice to treat the raw water and remove its iron content before mixing it with the softener effluent. (See Iron Removal Section above.)

Cold Lime Soda Process

In the cold lime soda process, the hard water is treated with lime or lime and soda ash, added in such proportions and amounts as to precipitate the bulk of the hardness in the forms of calcium carbonate and magnesium hydroxide. The function of the lime is to remove free carbon dioxide; to change the calcium bicarbonate to the insoluble carbonate and when magnesium hardness reduction is required, to precipitate it as magnesium hydroxide. The function of the soda ash is to convert the chlorides or sulfates of lime and magnesia to the carbonates.

In waters which contain little or no sulfate (or non-carbonate) hardness, treatment with lime alone will be sufficient to reduce the hardness to the required tolerance. On the other hand if the non-carbonate hardness exceeds some 3 grains per gallon, the use of soda ash as well as lime is required to produce a 5 grain per gallon effluent. In either case, the addition of a small amount of a coagulant—usually about 20 ppm. of aluminum sulfate—is desirable in order to form an easily settled floc.

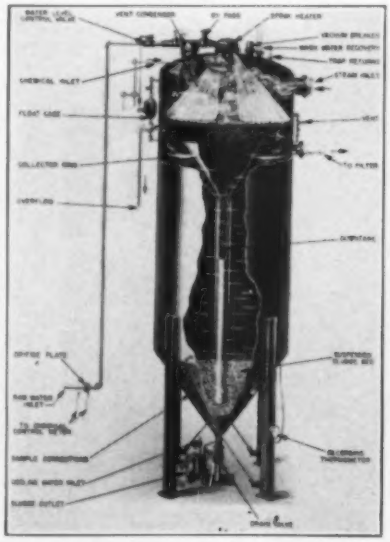
Sludge Blanket Softeners

In the older or so-called "conventional" cold lime soda water softeners, treatment and settling was effected in large settling tanks or basins and the effluent was usually recarbonated before passing through the filters in order to prevent "growth" of the filter granules and "after deposits" in the distribution system. In the newer, sludge-blanket type of equipment, the treated water, by being brought in intimate contact with previously formed precipitates, is brought into chemical balance so that recarbonation is unnecessary unless a lowering of the pH value is required.

For the purpose of explaining this system, the "Permutit Spaulding Precipitator" will be described. The "Precipitator" is available in two basic types, the vertical and the horizontal and in sizes ranging from 10 mgd. per unit down to small units for carbonated beverage plants and other such uses, with capacities of only a few thousand gallons per day. Also it is possible to convert many of the older settling basins and tanks to the "Precipitator" type by remodeling their interiors and thus increasing their efficiencies, lowering their lime requirements and increasing their capacities.

The vertical "Precipitator" may be described as a cone, cut in half, the smaller portion, with the largest diameter downwardly disposed, being placed in the center of the larger portion, with the largest diameter upwardly disposed and with, of course, a space between the lower rim of the downcomer and the bottom of the tank. This downcomer is equipped with a centrally disposed, vertical agitator. The horizontal "Precipitator" differs from the vertical type in that the outer chamber is a rectangular concrete tank; that the inner chamber or downcomer is formed by sloping partitions and that two horizontal agitators are employed in the inner chamber, these being driven by a motor placed in a drive pit at one end of the Precipitator.

The principles of operation are the same in both types and may briefly be described as follows: The raw water and the chemicals enter at the top of the inner chamber and pass downwardly through it, the agitator serving to thoroughly mix the chemicals with the water and to keep the precipitates, formed by the reactions, in suspension. Emerging at the bottom of the inner chamber, the treated water flows upwardly through a suspended blanket of previously formed sludge. As the cross-sectional area of this outer chamber increases from bottom to top, the vertical velocity of the rising water constantly decreases until a level is reached beyond which it cannot lift the precipitates. In practice, there is a clear line of demarcation between the top of the sludge blanket and the clear effluent rising above it to the outlets.



Hot Process Softener—Sludge Blanket Design

The intimate contact thus obtained between the precipitates and the water results in a complete utilization of the added lime; elimination of super-saturation and after-precipitates; and, due to the filtering action of the sludge blanket, the production of clearer effluents and longer filter runs.

The depth of the sludge blanket is kept between specified limits by bleeding off sludge, through sludge concentrators, at approximately the same rate at which new sludge is formed. These sludge concentrators are relatively small compartments in the bottom of the outer chamber through which there is no upward flow of water and in which, therefore, the requisite part of the sludge settles and concentrates to about 10 per cent solids.

In municipal practice, the effluent from the "Precipitator" is filtered before passing to the clear well. The filters used are usually of the gravity type and therefore need no detailed description. In addition to their use in the cold lime soda water softening process, "Precipitators" may be used for the coagulation of turbid or colored waters.

Combination Lime Zeolite Process

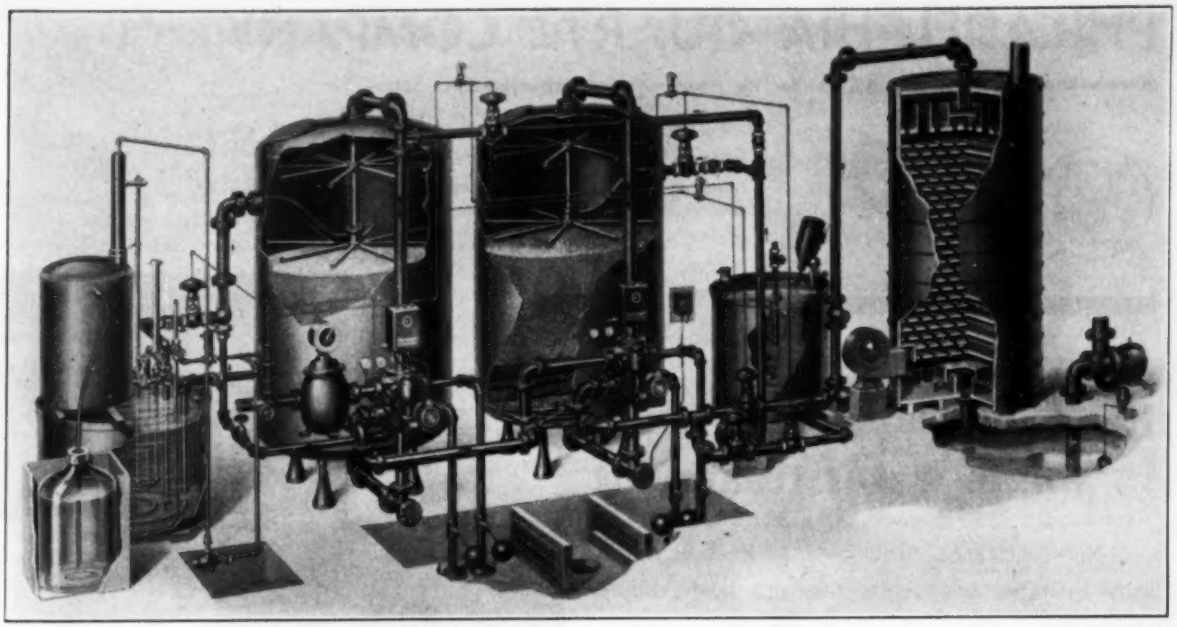
In the combination lime zeolite process, the water is first treated with lime to reduce the bicarbonate hardness. The filtered effluent is then passed through a zeolite (sodium cation exchanger) water softener to remove the noncarbonate hardness and residual carbonate hardness. With waters containing appreciable amounts of noncarbonate hardness, this process shows very economical operating costs as the cheapest method of removing bicarbonate hardness is with lime and the cheapest method of removing noncarbonate hardness is with zeolite.

Further advantages with this process are that it reduces the alkalinity and total solids content and that, where iron removal is concerned, the iron can be removed in the first stage of the process by introducing enough air to oxidize the iron to the ferric state. In using this process for municipal water softening, the usual 5 gpg. effluent may be obtained by mixing the requisite portion of the filtered lime treated water with the zeolite effluent.

The system used consists of a cold lime softener plus filters plus zeolite water softeners. If the pH value of the lime treated water is too high, a slight recarbonation will serve to reduce it. If the raw water is an iron or manganese bearing water, or, if the free carbon dioxide content is high, an aerator is employed ahead of the cold lime softener. This may consist of a coke tray or wood slat tray aerator; or, if only a slight aeration is needed, running the water over a few steps or baffles before it enters the cold lime softener will be sufficient; or, the air may be introduced by an air grid and compressor in a compartment ahead of the lime treatment.

Demineralization Process

While the hydrogen cation exchanger process, the ion exchange demineralizing process, find other uses than in the treat-



Automatic Demineralizing Plant with Degasifier

ment of municipal water supplies, a brief description of them may be of interest. In the hydrogen cation exchanger process, the cation exchangers used are of the organic or non-siliceous types. These organic cation exchangers may, when regenerated with salt, be used in the same manner as the siliceous zeolites. Their most interesting use, however, is on the hydrogen cycle.

On the hydrogen cycle, the cation exchanger is regenerated with acid, usually sulfuric acid. The hydrogen thus introduced into the cation erchanger will exchange hydrogen for calcium, magnesium and sodium ions.

If a water containing nothing but the bicarbonates of these metals is passed through a hydrogen cation exchanger, the calcium, magnesium and sodium will be completely removed and nothing but free carbon dioxide will be left in the effluent. As the carbon dioxide is easily removed by aeration, such an aerated effluent would be practically the same as distilled water in composition.

However, if sulfates and chlorides are also present, these would appear in the effluent as the corresponding acids. These may be neutralized by the addition of soda ash or by mixing with the requisite quantity of water softened on the sodium cycle.

On the other hand, if complete removal of the sulfates and chlorides is required, then the effluent from the hydrogen cation exchanger is passed through an anion exchanger which completely removes the sulfuric and hydrochloric acids formed by the hydrogen cation exchanger. The carbon dioxide is then removed by aeration resulting in an effluent equivalent to a distilled water. As the cost of demineralization is only a very small fraction of the cost of distillation, this process is now coming into very extensive use wherever a water of such high quality is required.

Hot Lime Soda Process

The hot lime soda process, too, may be of interest, although not used for municipal softening. It is confined almost exclusively to the softening of boiler feed waters as the process is carried out at the boiling point. The softener consists of a tall enclosed steel tank designed usually to withstand a pressure of about 10 psi. In the top of the softener is a spray heater, which heats and deareates the water to less than 0.3 ml. per liter of dissolved oxygen.

The lime and soda ash are fed to the hot water in the top of the softener where it reacts with the hardness producing a sludge. In the newer sludge blanket type design, the water flows through a downcomer in the center of the softener and then rises through a blanket of this suspended sludge. In the older types, the flow was downward to a short distance above the bottom where the treated water was drawn off through a cylindrical uptake while the sludge settled to the bottom.

The sludge blanket type has rapidly come into popular favor particularly where the silica content, as well as the hardness, requires reduction or removal and it is built in a number of designs for handling makeup alone or both makeup and various amounts of condensate and for either a deaeration to 0.3 ml. per liter of dissolved oxygen or complete deaeration to less than 0.005 ml. per liter. In the latter case, the complete deaeration is effected by a clever use of the steam required for the primary heater; this steam being blown through the hot, softened and partially deaerated water in a deaerator compartment before being used in the primary heater.

The hot process softener will reduce the hardness to below 1.5 gpg. (25 ppm.) by the use of lime and soda ash alone and to as little as 1 or 2 ppm. when phosphate also is used. Also, by the use of dolomitic lime or activated magnesia, the silica content may economically be reduced to practically any desired figure.

The effluent from the hot process softener is filtered through pressure filters using a non-siliceous filter medium such as "Anthrafilt." These filters are periodically backwashed with hot softened water from the settling tank by means of a special backwash pump and the backwash water is returned to the top of the settling tank, thus recovering it. Since the process is carried out at temperatures around the boiling point, the softener tank and filters are usually lagged with insulating material to prevent heat losses. As previously stated, this process is almost exclusively limited to softening boiler feed waters, the few exceptions being where a very hot, softened process water is required.

PHILADELPHIA QUARTZ COMPANY

Manufacturers of N® Sodium Silicate for the Preparation of Activated Silica Sols

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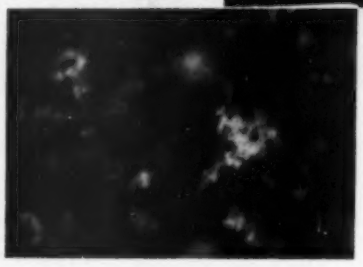
Activated silica sol is made with N Silicate of Soda (41° Baume) and a reactant chemical at the plant where it is used. PQ's N-Sol Processes using reactants as noted below are licensed without royalty. (The use of sulphuric acid is covered by U. S. Pat. 2,217,466, J. R. Baylis, City of Chicago.)

Coagulation with alum alone



Coagulation with alum plus activated silica sol

PQ Assistance

Samples of N Silicate of Soda and directions for making jar tests are available on request. PQ engineers are glad to share our experience with activated silica sol as an aid in water treating problems. Ask for free booklet, "Treatment of Raw and Waste Waters."

COAGULATION	PROCESS	REACTANTS	ADVANTAGES
Raw Water Improves quality Lengthens filter runs Removes high color Reduces turbidity Removes manganese Removes magnesium	N-SOL-A (U.S. Pat. 2,444,774)	ammonium sulphate	Ease of preparation, either batch or continuous. Requires smaller equipment.
Waste Water Prevents stream pollution Clears effluent	N-SOL-B (U.S. Pat. 2,310,009)	alum	Reactant readily available, inexpensive.
In Such Industries as: Paper Petroleum Metal Finishing Plating Food Textile	N-SOL-C (U.S. Pat. 2,567,285)	chlorine	Reactant usually available where sterilization is normal practice.
Also Radio Active Waters	N-SOL-D	sodium bicarbonate	Used where an alkaline salt is desired. For boiler feed water where ammonia is not desired.

Preparing and Using Activated Silica

By CHARLES A. BLACK
Pres., Black Labs., Inc., Gainesville, Fla.

ACTIVATED silica, although its application to water treatment is relatively new, actually has a long history. More than 150 years ago, Pott reported the preparation of a "semi-solution" of silica, but Graham is usually credited with the discovery of silica sol.

The first successful efforts to use silica sols on a large scale in water treatment took place in 1936. The work was done independently and concurrently by J. R. Baylis at Chicago and by Graf and Schworm at St. Louis. Baylis showed that the addition of sulfuric acid to a dilute solution of sodium silicate, with proper aging, could improve the alum coagulation of Lake Michigan water appreciably. Graf and Schworm demonstrated, in both laboratory experiments and plant scale trials, that solutions of alum and sodium silicate of approximately equal concentrations could be used as an effective coagulant aid. It is surprising to note that, as early as 1884, Graham was so close to the views now considered modern. Graham has been generally credited with introducing the terms sol, gel, and peptization.

Definition of Terms

Because activated silica, although in limited use for a great many years, has not as yet been widely accepted throughout the country as a conventional coagulant or coagulant aid, some of the terms employed in this paper may not be familiar. Consequently, it has been deemed advisable to include the following definitions applicable to the theory of activated silica:

Activated silica. This term designates a negatively charged colloidal particle formed by the reaction of a dilute sodium silicate solution with a dilute solution of an acidic material or other activant.

Sol. This is a general term applied to colloidal dispersions as distinguished from true solutions.

Gel. A silica gel is a heavily hydrated, interlaced, fibrillar or brush heap structure of very large polysilicic acid molecules, with the spaces filled with water or dilute silicate solution.

Gel induction time. The time interval between the addition of the activant to the sodium silicate solution and the first determinable gel formation is the "gel induction time" (sometimes called "gel time").

Micelle. This term, taken from the French, has been construed to indicate an internal-phase particle that possesses a double layer of charges of opposite sign adjacent to the surface. As applied to activated silica, it usually refers to a particle size varying between 0.1 and 1.0 mμ.

Mole ratio. As applied to activated silica, this term refers to the ratio of the number of moles of activant to the number of moles of sodium oxide in the silicate.

Percentage neutralization. Taking a 1:1 mole ratio of activant to sodium oxide content as unity, or 100 per cent, this term expresses as a percentage the ratio of equivalents of activant to equivalents of sodium oxide content added in the neutralization process.

Parts per million activated silica ($^-SiO_2^-$). This term represents the parts per million available $^-SiO_2^-$ micelles present. These micelles have a negative charge and should not be confused with SiO_2 as normally found in water supplies.

Methods of Activation

Activated silica sol, prepared by the partial or total reaction of the sodium oxide content in sodium silicate, has often been applied successfully as a coagulant aid. The process involves the reaction of a suitable grade of sodium silicate, such as one having a ratio of 1 part Na_2O to 3.2 parts SiO_2. A typical analysis is: Na_2O, 8.9 per cent; SiO_2, 28.7 per cent; and H_2O, 62.4 per cent. The activation of sodium silicate with strong acids follows a pH curve similar to that for the reaction of a strong acid and strong base.

Probably the first activated silica sol successfully used as a coagulant aid in the treatment of raw water was developed by Baylis[1], working in Chicago on Lake Michigan water. He found that, when the alkalinity of sodium silicate was partially neutralized by sulfuric acid, it acted as a coagulant aid for this water. The Baylis process involved the addition of a diluted sodium silicate solution to a level of 1.5 per cent SiO_2 and the addition of sulfuric acid sufficient to neutralize approximately 85 per cent of the alkalinity. This solution was aged for 2 hr and then diluted to a level of 0.6 per cent SiO_2, producing a very efficient coagulant aid.

The Graf-Schworm process[2] involves the addition of 1 per cent alum solution to a 1 per cent silicate solution in a ratio of 4 parts of alum to 1 part of silicate. This mixture is then used immediately as a coagulant aid.

A method of activation developed by Hay[3] involved the use of ammonium salts. This method differed from both the Baylis and Graf-Schworm processes in that it did not involve alkalinity neutralizaton and the pH of the final silica sol was much higher than in either of the other methods. Hay also suggested the use of carbon dioxide, sulfur dioxide, sulfur trioxide, chlorine, and acid salts as activating agents, as well as the concept of continuous activation. The Hay process for activating silica is commonly called N-Sol A. The usual method of producing this sol is to mix diluted silicate and ammonium sulfate solutions in equimolar proportions, to age this mixture at a concentration of 2 per cent SiO_2 for 1 hr. and then to dilute it below 1.3 per cent for storage to prevent gel formation. This sol has less tendency to gel and can be safely stored and used at approximately twice the safe storage concentration of the Baylis sol.

The Baker-Dedrick sol[4], commonly called N-Sol B, is produced by adding dilute solutions of sodium silicate to dilute solutions of a metal salt capable of forming an insoluble silicate. These solutions are mixed in equimolar proportions, aged, and added to the water treatment system or diluted to prevent gel formation.

Many other activants have been used to form activated silica sols, but the methods previously mentioned are the most important insofar as general acceptance and basic work are concerned. Silica sols made by the hydrolysis of silicon tetrachloride have only a slight effect on coagulation. Those prepared by the passage of a diluted soluble silicate through an ion-exchange resin have little, if any, coagulant activity.

Theory

The internal-phase fibers of a silicic acid gel are regarded by Hurd and Miller[5] as consisting of condensed silicic acid molecules that form long,

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branched chains profusely entangled. This condensation is produced by the splitting off of the water, starting at first by a reaction between simple molecules and continuing between the larger molecules thus formed until a network develops. The vast surface created by such a brush heap structure of combined silicic acid molecules can account for the adsorption of the water molecules and for their being held in a more or less rigid condition. According to Hurd and Miller, any condition that tends to alter the rate of reaction accordingly affects the rate of the setting of the gel. During the aging period, the low-molecular-weight polymer of silicic acid formed by the neutralization of the silicate alkalinity by acidic material increases in size. If the aging process is not stopped by dilution, addition of alkali, or other means, the mixture gels. By controlling the aging time, the size of the silica micelle can be varied over a wide range. During aging, the more soluble silica changes to a colloidal form that does not react with ammonium molybdate in the usual analytical test for silica.

Assuming that the gelatin is due to a condensation reaction of this type, fastest gelling should occur near the pH of least ionization, where there is a minimum of repulsion forces between similarly charged silicic acids or hydroxides or an equal number of positively or negatively charged species containing silicon hydroxides. The occurrence of such a maximum rate of gelation at an initial pH of approximately 7 is evidence that the silicic acids are much stronger than is ordinarily supposed. The increase in pH during aging and gelation indicates that the polysilicic acids forming are weaker and are more extensively hydrolyzed. Published data[6] clearly shows that the gelling power of ammonium salts is not due entirely to acid formed by hydrolysis, as they form gels at pH values only slightly less alkaline than the sodium silicates themselves. Systems of silicates with acids do not form gels at these pH values. The sodium aluminate-silicate mixtures have higher pH values than silicate solutions alone. The ability of ammonium salts to gel sodium silicates is, therefore, probably due to the formation of slightly ionized, heavily hydrated, insoluble gelatinous salts.

The sodium silicoaluminate gels formed when sodium silicates and aluminates are mixed contain sodium ions that are not removable by extensive washing with water. These sodium ions are replaceable with other cations like calcium and magnesium. Such products, usually termed artificial zeolites, are used extensively in water treatment. Because aluminum or aluminate ions, as well as the silicates, can be regarded as polyfunctional, the formation of a silica alumina gel probably involves copolymerization reaction.

Thus, it can be seen that there are at least four distinct methods of forming activated silica sols and silica gels: (1) alkalinity neutralization with acids or acid salts; (2) the use of ammonium sulfate to form slightly ionized, heavily hydrated gelatinous salts; (3) the use of sodium aluminate to form silico-aluminate sols; and (4) the addition of dilute solutions of a metal salt to sodium silicate to form insoluble salts.

In general, the rate of gelation of mixtures of 3.3-ratio sodium silicate with the various gelling agents increases in the following order: ammonium sulfate, sulfuric acid, hydrochloric acid, and sodium aluminate. Under certain conditions this order does not hold, however. The mole ratio of the gelling reagent to the alkali of the silicate does not affect the gel time as much with the aluminate and ammonium salts as it does with the acids.

The actual point of gel formation is usually determined by the loss of uniform fluid flow, the appearance of breakage planes when the mixture is tilted, and the adherence of solid gel to the glass wall of the container. The gel induction time obtained in this manner is reproducible within 2 per cent and usually corresponds fairly closely to the "time of set" determined by the "tilted-rod" method extensively used by Hurd and collaborators.

It has been found[6] that, for best results, the aging period for activated silica sols should range between 10 and 50 per cent of the actual time necessary for gel formation. Optimum results are usually obtained when the aging period is approximately 25 per cent of the gel induction time.

Carbon Dioxide and Chlorine Activation

The three methods of silica activation probably most widely used at present employ sulfuric acid, alum, or ammonium sulfate. At least two additional methods, developed in recent years, have shown considerable promise, however. One of these involves the neutralization of the alkalinity by the use of carbon dioxide. This method is of special interest where carbon dioxide is available from the burning of lime sludge in softening operations or as a constituent of burner gases. This activation process, utilizing gases from the exhaust of diesel engines containing 4-5 per cent carbon dioxide gas, is now being employed at Miami, Fla.[1] Activated silica is prepared in batch quantities, and approximately 30 mgd of water is being treated with approximately 2 ppm "SiO_2".

Another process coming into wide favor at present utilizes gaseous chlorine for activation. This method of activation has many advantages. The hypochlorite produced in the reaction contains, in effect, the same oxidizing power as the original chlorine. Hence, none of the chlorine applied is lost, and it is available for disinfection and oxidation of organic materials. Thus, the actual cost of chlorine as an activator is nothing, as it will replace an equivalent amount already used in the filter plant. The relatively low solubility of chlorine in water complicated the development of a continuous process for the production of this sol, but this difficulty has been overcome by at least two major chemical-feeder manufacturers. One of these feeders utilizes a high percentage of activation, a relatively high "SiO_2" content of the aging mixture, and a very low aging time. The solution to be used is prepared continuously and employed immediately after preparation.

Benefits of Activated Silica

The application of activated silica to water treatment has brought numerous benefits never before obtained with a coagulent aid. Baylis' study[7] showed that, in Lake Michigan and synthetic waters, the sol decreased the time required to form a floc; increased its size, toughness, and density; permitted more rapid settling; produced a clearer settled and filtered water; and lengthened filter runs. The sol made it possible to use higher flow rates and coarser filter media and produced good water over a wider pH range. Magnesium could be removed at a lower pH by using the sol. If considerable magnesium was present, it could be coagulated by lime and silica alone.

The first successful plant scale use of activated silica sol employing ammonium sulfate was made in 1943 by Black[8] in a Florida plant. The addition of 4 ppm silica as "SiO_2" prior to feeding 85 ppm of lime and 8.5 ppm alum produced a larger, tougher, heavier floc that settled faster and resulted in increased color removal

and clearer water. In this plant, the addition of 4 ppm silica replaced a dosage of 70 ppm alum as a coagulant with a very substantial financial saving. At approximately the same time Black also initiated the application of activated silica to a softening plant, using sulfuric acid as the activant. Since then activated silica has become a standard coagulant for lime softening in Florida, and, to some extent, has replaced alum. It is also used as a coagulant aid in the treatment of surface waters with alum. It gives a tougher, heavier, and faster settling floc than alum alone.

The benefits observed when activated silica has been used in raw-water coagulation are many, although all are not obtained in every instance. Often a saving in the cost of chemical treatment results from the reduction in the amount of alum or iron salts needed for good coagulation. Sometimes the saving stems from increasing the capacity of the equipment by creating a heavier floc, thus making the existing equipment serve at higher capacities and either postponing the necessity for expanding the plant or reducing the initial cost of new installations. Almost always activated silica in the proper proportion increases the speed of formation and the size, density, and strength of the floc.

It should not be assumed that, because silica is present in a raw water to the extent of 10-20 ppm, activated silica will not be beneficial. The natural and activated forms of silica differ, or at least produce different effects. Usually, adding activated silica to the raw water along with the other coagulants will actually decrease the silica content of the finished water, because more and better coagulation is obtained.

Activated silica has been demonstrated to be a very economical method of treatment. A recent installation in an eastern steel mill showed almost a 50 per cent reduction in water treating cost when activated silica sol treatment was started. Hazlip[9] stated that, at Houma, La., the use of activated silica and reductions in the amount of other chemicals fed decreased the cost from $41.41 to $20.72 per million gallons of water treated. The cost of silica sol application is estimated at 35-50 cents per part per million "SiO_2" for each million gallons of water treated.

Black[10] found activated silica highly effective when used in conjunction with the lime softening of Florida well waters. The process usually consists of softening with excess lime and using approximately 8.5 ppm alum as the coagulant. In some plants, the silica is substituted for all of the alum; in others, the addition of alum with the silica has been found desirable. With the silica treatment the floc particles are large and "leathery." Turbidities of settled waters are reduced greatly and the filter runs are lengthened. Black states that, although activated silica used in conjunction with another coagulant should properly be called a coagulant aid, the time has come to recognize that it may, and often does, act as a coagulant in the truest sense of the word.

Plant Applications

It is important to learn the optimum proportions of activated silica and other coagulants and the proper order of addition. These factors should be studied by means of jar tests, which, if carefully conducted, give a good indication of results to be expected in plant practice. The amount of activated silica usually required varies from 2 to 15 ppm. Excessive amounts of silica destroy the effectiveness of the alum, and no coagulation is obtained. The point of application of the silica is often a critical factor. In combination with alum, negative results are sometimes obtained when the silica is added ahead of the alum; whereas, when the silica is added immediately after the formation of a pinpoint floc, a large, heavy alum floc results. Very often, however, it is found that the silica should be added to the raw water ahead of the other chemicals. The optimum procedure must be determined by jar tests and plant trials.

The effect of temperature on the results obtained with activated silica was investigated by Spencer, Middleton, and Merrill[11]. It was found that activated silica appreciably lessened the time necessary for floc formation at low temperatures. The use of activated silica at low temperatures also greatly decreased the problem of after-precipitation of alum.

Effect on Filter Runs

It has been reported by several persons that activated silica has decreased filter runs. Upon investigation by the individuals concerned, it was found that a sticky, gelatinous film had formed on the top of the filter, thus plugging it. Several explanations for this phenomenon have been found. If only part of the sodium alkalinity is neutralized, the floc formed may be sticky and could, under unfavorable circumstances, cause filter plugging. No difficulty of this type is encountered with ammonium alkalinity. Filter plugging occurring when Baylis sol of 85 per cent neutralization was used disappeared when the silicate was 95 per cent neutralized with sulfuric acid or 100 per cent activated with ammonium sulfate. A change in the alum-silica ratio or in the relative points of application of alum and silica may also eliminate filter plugging.

In one installation, it was found that the proportion of mud and floc indicated that backwash was decidedly inadequate. Surface wash units were installed in the filter beds. With the efficient surface wash, a negligible amount of dirt remained after backwashing, and filter plugging was entirely eliminated. Because a certain quantity of floc is carried to the average filter bed from the sedimentation basin, the application of silica is warranted only if it is known that an efficient backwash is possible. If the silica-alum floc, which is dense and slightly sticky, cannot be washed properly from the bed, it accumulates in serious proportions, increasing the frequency of backwash to a point at which operation becomes very difficult. This problem is especially likely to arise if the filter beds are dirty before the application of silica.

Conclusions

Activated silica sols are truly a welcome addition to the family of chemicals available for water treatment. When properly applied in correct dosages activated silica will almost always improve the coagulation and chemical quality of the water treated. Activated silica, like all other chemicals used in water treatment, must, however, be properly applied or its beneficial effects cannot be realized. It is the opinion of the author that future applications of activated silica in this country will be numerous and that the trend will be toward continuous activation with carbon dioxide and chlorine.

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Discussion

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The author has outlined the uses and characteristics of activated silica and has shown that many reactants can be employed. He has indicated that heretofore activated silica has been prepared largely by the batch method and has pointed out that continuous methods are desirable but not as yet widely accepted. It is the purpose of this discussion to describe how chlorine is used in the continuous activation of silica.

For several years this method has been employed on a batch basis in paper making and in the clarification of domestic water, with makeshift activation units. Klinger[1] and others who have investigated the applicability of chlorine-activated silica have found it to compare very favorably with earlier methods. Chlorine-activated silica is especially attractive because all the chlorine used for activation is available in full strength to perform the normal functions of chlorine. This means that every pound of chlorine used in activation can be subtracted from the normal prechlorine dosage. In plants where prechlorination has not been practiced, this silica activation process will yield all the benefits of prechlorination in addition to its primary function of activation, and, if the chlorine demand of the raw water is not too high, there will be a good chance that postchlorination can be reduced to some degree.

The activation of silica with chlorine differs from other methods in several respects: the aging time has been greatly shortened, the silicate is pumped full strength, and the process is continuous. The procedure is relatively simple because it entails the control of only three ingredients—chlorine, water, and sodium silicate. As in other methods, the sodium silicate is diluted and the alkali is partially or wholly neutralized. This neutralized solution is then aged, further diluted, and fed to the point of use.

Description of Equipment

In equipment developed for this process, the dilution water and chlorine are conducted into a reaction chamber where the sodium silicate is diluted to the proper point and the chlorine neutralizes the alkali to the proper degree. Aging takes place in the same chamber. The finished product is removed by an ejector system, which, in some ways, is the heart of the process. In addition to removing and transporting the finished product to the point of use, the ejector also creates the vacuum needed to meter the flow of chlorine, pulls in the air used in mixing, and provides the necessary final dilution water for stabilizing the finished solution.

The finished solution contains, in addition to silica micelles ($^{-}SiO_2^{-}$), all of the chlorine used in the neutralization of the alkali. The process may be expressed as an equation:

$$Na_2O{\cdot}SiO_2 + HOCl + HCl \rightarrow {}^{-}SiO_2^{-} + NaOCl + NaCl + H_2O.$$

It will be noted that the $^{-}SiO_2^{-}$ does not enter into reaction with chlorine but is simply released from captivity, as it were. The oxidizing power of the chlorine used remains, in the form of sodium hypochlorite (NaOCl). This provides the basis for the previous statement that all the chlorine used is available for the normal functions of that chemical. The pH of the solution delivered to the point of application ranges from approximately 7.0 to 8.5.

Operation is simple. Chlorine, water, and sodium silicate feeds are set in accordance with a chart showing the amount of each required to produce the proper grade of activated silica. Chlorine feed is calibrated in pounds per 24 hours, water in gallons per minute, and sodium silicate in gallons per day.

This system works very close to the minimum sol life of the activated silica. When $^{-}SiO_2^{-}$ is released, the time required for it to form a gel will depend upon the initial dilution and the degree of activation. Thus, in the activation of silica, the sol life or gel time is controlled. In batch treatment, the sol is usually aged several hours and then diluted to a working strength of approximately 0.5 per cent. In the system under discussion, the sol life is relatively short—minutes instead of hours—and can be controlled. The sol is made and used within a matter of minutes, thereby decreasing the need for holding tanks and greatly simplifying the operation.

Good results in the preparation of activated silica depend to a considerable degree on proper initial mixing. The air used for this purpose in the continuous chlorine method is drawn into the reaction chamber by the vacuum created by the ejector. Entering at the bottom of the chamber, the air bubbles upward against the downward flow of silicate and water. The appearance of a bluish color or haze is evidence of properly activated silica.

Difficulties due to uncontrolled gelation at unpredictable times have been completely eliminated in this system. The only place where any gel can accumulate is the reaction chamber, from which it can be removed easily by loosening two wing nuts, thus releasing the entire jar. A rub of the hand on the inside removes all gel, and, after replacement of the jar, the equipment is again ready to run. The whole operation seldom requires more than a few minutes.

The ejector which removes the activated silica from the reaction jar and provides a vacuum for the operation of the whole system is of such size that the water used produces a final dilution of approximately 0.5 per cent. This final dilution inhibits further micelle growths, so that the product then can be transported any reasonable distance without danger of gel formation. This is equivalent to the final dilution in the batch method that constitutes the working solution.

This system has passed through the field experimental stage. Units are now in operation on a great variety of waters and purification systems. Where the use of activated silica is justified, the chlorine activation process is proving as efficacious as other methods of activation, and the unit has demonstrated its reliability.

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Quick Freezing Small Pipes for Repairs

By JOHN L. FORD

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WHEN curb valves on water services have to be replaced or when street widening makes it necessary to lengthen the service to the curb valve, it is a big advantage to be able to shut off the pressure. Shutting off the corporation cock at the main generally involves too much digging and expense to be practical unless it is the only way.

In some water works it has been common practice for many years to temporarily freeze water in pipes to serve as a plug in the line and prevent flow during valve changing or other repair and extension work. I recall my father telling how he used a box about 4 in. square and a foot long with notches in the end to slip under service pipes and then fill with ice and salt. The principal requirement for service pipe freezing is stopping the flow during the process, or at least cutting it down to a rate which will permit freezing. In replacing defective curb valves it is generally possible to cut the flow down far enough.

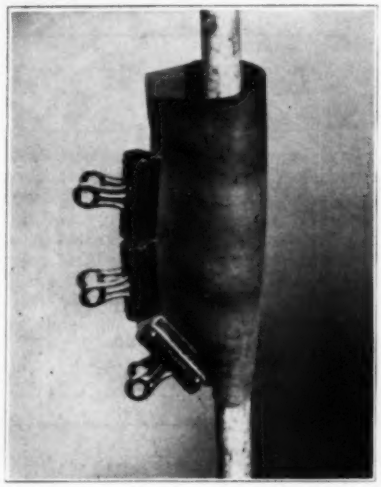
Considering the simplicity and ease of service pipe freezing it has always been surprising that it is not used oftener.

The use of dry ice (solid carbon dioxide) for pipe freezing probably dates from the time when this material first became available. Its principal advantage is that it is so cold that it works amazingly fast. Also it is clean to handle and is now easily obtainable from almost any frozen vegetable distributor or ice cream shipper.

Simple Method of Freezing Service Lines

Here is a quick way to freeze water in pipes with dry ice. The procedure is certainly simple and fast. A piece of old inner tube about 8 in. by 10 in. is centered under the pipe and then brought up and fastened together with wide and strong paper clamps. The rubber should not be stretched tight from end to end but should be a little loose so as to form a pocket around the pipe—see cut.

For freezing a ¾ in. pipe a piece of dry ice about as big as a tennis ball and weighing about one pound is ample. This is placed in a cloth and then pounded into "snow" with a hammer, board or stone. The "snow" is then poured into the rubber pocket and about one-fourth pint of alcohol is poured in on top, the two ingredients making a wet mush which is so cold and



Suggested Arrangement for Freezing Vertical Pipe

(To make liquid tight joint around pipe press clay, chewing gum or wax into corner between pipe and bottom clamp.)

makes such good contact with the pipe that the water inside is quickly frozen. Any alcohol, anti-freeze or even rubbing alcohol can be used. Gasoline or naphtha are also satisfactory though these may be hard on the rubber. However, old tire tubes can be had for the asking at most service stations so the cost of the rubber makes no difference and gasoline may be more readily available than alcohol.

When the flow in the pipe can be stopped entirely this procedure will freeze the water in a ¾ in. steel pipe solid in from two to five minutes. With a flow of 1/30 gpm. (about one-fourth pint per minute) the flow will stop in about the same time. This flow is more than a drip, coming out of a smooth ended small faucet or small pipe as a steady stream about 1/16 in. in diameter and breaking into drops some three inches below. The experiments on which these results were observed were made with water of about 65° F.; colder water would freeze a little faster. It takes several times as long to freeze a service with dry ice when no liquid is added. Apparently this is because the liquid makes better contact with the pipe and conducts the heat away faster.

In actual work in the trench there may be a small drip from the valve which can be watched to see when the flow stops to indicate that the pipe is frozen.

When there is no leak or drip to watch, the best procedure is to leave the valve closed for five minutes after the dry ice and liquid are poured around the pipe and then open the valve cautiously, keeping in mind that there will be a small amount of water under pressure between the ice plug and the valve which may deceive the operator into thinking the ice plug is not yet solid. If the flow continues, close the valve again before the water thaws much of the ice that has formed, and let the freezing action continue a few minutes longer and again try for flow.

After the pipe is frozen solid it will remain so as long as there is any dry ice left in the envelope and more can be added if desired. After the necessary piping changes have been made the rubber is removed and warm water can be poured on the pipe to thaw it, or a torch can be used. The rubber can be re-used many times and the expense of this method is only 15 cents for material. The time required is only a few minutes in most cases. There is no damage to any kind of pipe by this process, but of course dry ice should never be handled with the naked hand.

If the flow cannot be reduced to about half a pint per minute the pipe cannot be frozen as mentioned above because the warm water passing through keeps a small opening melted through the ice. A longer pocket providing more contact would doubtless freeze a greater flow but it is obviously impossible to stop large flows unless means are available to reduce the leak to a rate that will freeze within a reasonable time.

A Warning

A word of warning should be added about the use of dry ice. The carbon dioxide given off is not poisonous but it can cause suffocation and even death. The small amount used in pipe freezing and the natural ventilation available makes the danger in this work almost negligible. There is little fire hazard with alcohol or gasoline during the freezing because the concentration of carbon dioxide and the low temperature of the liquid prevent ignition.

(1) Pound the dry ice into "snow" in a cloth; pour it into rubber pocket around pipe.

(2) Pour about one-fourth pint of alcohol or gasoline on the "snow" and stir to mix.

(3) After 3 to 5 minutes the water in pipe is frozen solid; the repair can be made.

Color Code Your Plant

H. E. LORDLEY
Asst. Director, Dept. of Public Utilities, Richmond, Va.

A NEW word for the progressive plant operator to add to his vocabulary in discussing plant maintenance is COLOR. The superintendent of the smallest pumping station or the largest filtration plant can establish a "color code" for the identification of equipment as well as piping, both to facilitate maintenance and repairs and to improve the general appearance of the plant.

During the war, industrial plant managers realized the importance of proper identification of piping systems when many inexperienced employees were hired. Lack of such identification resulted in many unusual cross connections and costly shut-downs. This hazard was so pronounced that the American Standards Association published on July 16, 1945, a "Safety Color Code for Marking of Physical Hazards and the Identification of Certain Equipment." The plant operator should consult the American Standards Association's publications on the subject or establish his own code, as was done in the Richmond Filter Plant even prior to World War II.

Establishing A Color Code

The first step in any system is to establish a definite color code according to the character of the carious materials in the piping system. The ASA system is shown in Table I.

In this system all materials piped are listed and each assigned to one of the five classes, as illustrated in Table II.

TABLE I

Classification	Color
F—Fire protection equipment	Red
D—Dangerous materials	Yellow or orange
S—Safe materials	Green, or the achromatic colors white, black, gray or aluminum
P—Protective materials	Bright blue
V—Extra valuable materials	Deep purple

TABLE II

Material Piped	Classification
Alum solution	S
Carbon dioxide	D
Chlorine	D
Ammonia	D
Soda ash solution	S
Water	S
Steam	D
Water—fire protection	F

Richmond Markings

Table III illustrates the system used in Richmond for identification of pipes common to water plants. However, this system was established in 1940 and is not always in conformity with ASA recommendations listed above.

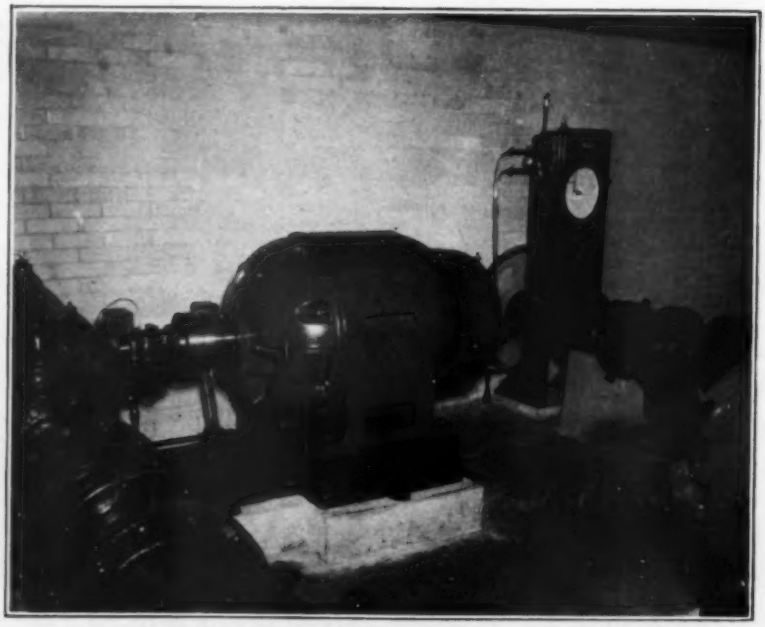
The system has the advantage of a larger number of colors and results in a variety of hues in an otherwise monotonous piping system. Many favorable comments have been received from visitors on this color arrangement and particularly from classes of school children.

Methods of Application

The second step requires careful consideration and study in selecting the actual method of applying the colors selected above. The entire length of pipe, valves and fittings may be painted the designated color, or the alternate method of painting color bands on piping having a uniform color may be used successfully. For example, it is often necessary to paint piping white or aluminum to improve illumination in pipe galleries, basements or dark areas, in which case an identifying color band 8 to 10 inches wide is painted adjacent to each valve, tee or branch pipe. However, the author has found one disadvantage in painting entire lengths without a change. It seems that painters become tired of using one color, which results in less footage per day covered than when switching to different colors. It is also interesting to note that in cases where one or more men are assigned the definite duty of painting their personal interest and pride in the work increases in keeping each line painted the proper color. New employees assigned to painting learn the piping system quickly. Having thus obtained a more thorough knowledge of the plant piping, they make more valuable employees when transferred later to the mechanical maintenance division or the operating division.

TABLE III

Piping	Color
Fire lines	Red
Sump pump lines	Red with white band
Raw water pumps	Red with white band
Drains on chemical machines	Red with white band
Waste water pump	Red with white band
Finished water	Dark green
Motors	Dark green
Electric conduit	Gray
Steam lines	Black
Chemical lines	Orange
Chlorine (gas or solution)	Yellow
Ammonia (gas or solution)	Yellow
Sulfur dioxide (gas or solution)	Yellow
Sewers	Light blue
Wash water pumps and lines	Light green
Air ducts	Aluminum
Hot water	Aluminum
Venturi meter lines and stacks	Brown



Color Code Paint Job in Fully Automatic Booster Pumping Station.

If a color band system is selected, this can be used in conjunction with stenciled words, letters and figures or more stripes of color at the edges of the band to indicate the exact identification of the system. For example, the uniform color of the system is aluminum with a yellow color band, indicating a dangerous material; however, chlorine, ammonia and sulfur dioxide are all dangerous, and it is necessary to further identify the system by the stenciled letters CL (chlorine), NH (ammonia), SO (sulfur dioxide), or Nos. 1 (chlorine), 2 (ammonia), 3 (sulfur dioxide), as illustrated in the accompanying sketch.

In selecting colors always remember that the reflective value of paints vary with the shade. Gray, which from a physiological or visual standpoint is situated about halfway between white and black, reflects approximately 25% of the incident standard white light, and is near the permissible limit of reflective value for poor illumination. In pipe galleries, aluminum or white paints give maximum illumination and increase the efficiency of maintenance operation.

Selection of Paints

The type and quality of paint used in a plant is often dependent on the judgment of the superintendent, and he is required by the Purchasing Department to submit specifications on every item. Several government publications are available to aid in the difficult job of selecting paint, two of the most useful being—

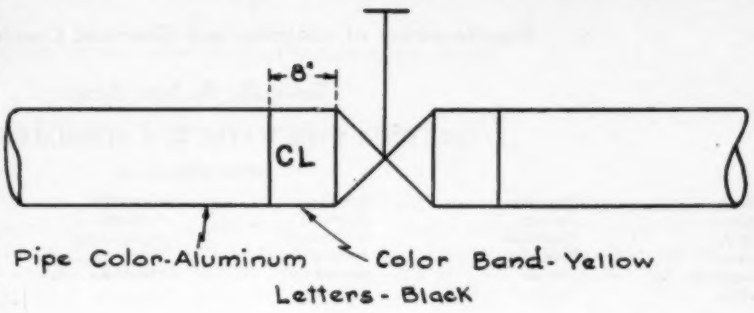
1) "Paint Manual." Report BMS105, dated October 11, 1945, available from the Superintendent of Documents, Washington 25, D.C., at a price of $1.

2) "Federal Specifications." Price List No. 75, available from the Superintendent of Documents, no charge.

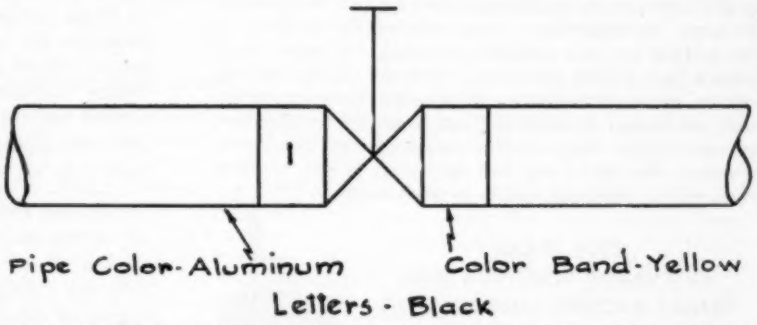
This list includes all specifications available on paint, copies of which may be purchased at the price listed; for example, Specifications TT-P-59 paint, ready mixed, international-orange, June 17, 1937, price 5c.

Our experience with the color code in Richmond has been more than satisfactory, and we have included the code in the specifications for our new thirty-six million gallon per day plant now under construction.

USE OF COLOR BANDS AND LETTERS



USE OF COLOR BANDS AND NUMBERS



Sketch Illustrative of Color Band System Used in Valve and Pipe Line Identification.

PROPORTIONING CONCRETE

Proportions of Mixtures			Material For One Cubic Yard Concrete								
			Gravel ¼" and under			Stone 1" and under, dust screened out			Stone 2½" and under, dust screened out		
Cement	Sand	Stone	Cement Bbls.	Sand Yards	Stone Yards	Cement Bbls.	Sand Yards	Stone Yards	Cement Bbls.	Sand Yards	Stone Yards
1	2	3	1.54	.47	.73	1.70	.52	.77	1.73	.53	.79
1	2	4	1.34	.41	.81	1.46	.44	.89	1.48	.45	.90
1	2	5	1.17	.36	.89	1.27	.39	.97	1.29	.39	.98
1	2½	4	1.24	.47	.75	1.35	.52	.82	1.38	.53	.84
1	2½	5	1.10	.42	.83	1.19	.46	.91	1.21	.46	.92
1	2½	6	.98	.37	.89	1.07	.41	.97	1.07	.41	.98
1	3	5	1.03	.47	.78	1.11	.51	.85	1.14	.52	.87
1	3	6	.92	.42	.84	1.01	.46	.92	1.02	.47	.93
1	3	7	.84	.38	.89	.91	.42	.97	.92	.42	.98
1	4	6	.83	.51	.77	.90	.55	.82	.92	.56	.84
1	4	7	.77	.47	.81	.83	.51	.89	.84	.51	.90
1	4	8	.71	.43	.86	.77	.47	.93	.78	.48	.95
1	4	9	.65	.40	.89	.71	.43	.97	.73	.46	1.01

1 Bag of Cement ..... = 94 Lbs.
1 Bag of Cement ..... = 1 Cu. Ft.

4 Bags of Cement ..... = 1 Bbl.
1 Bbl. of Cement ..... = 400 lb. Gross, 376 lb. Net

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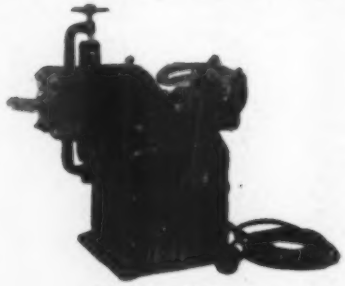
TYPE MASV AUTOMATIC SOLUTION FEED VISIBLE VACUUM CHLORINATOR

Where unusual or extreme fluctuations in water or sewage flow are encountered, the Type MASV meets the chlorination requirements. It embodies all the advantages of automatic proportioning of chlorine feed, and automatic starting and stopping with the outstanding features of the Visible Vacuum Control Chlorinator — rugged construction, simplicity of operation and low maintenance costs.

Type MASV Automatic Visible Vacuum Chlorinator

THE W&T HYPOCHLORINATOR



W&T Hypochlorinator

Chlorination of small water supplies involves problems which the W&T Hypochlorinator is especially designed to meet. This equipment feeds either calcium or sodium hypochlorite in solution form and is furnished in three types.

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day. Automatic Water Operated Hypochlorinators automatically proportion the chlorine solution to the flow of water and are especially adapted to small gravity water supplies with wide variations in flow.

The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

WT SILACTOR

The WT Silactor (pronounced SILL-actor) provides a system for the continuous production of activated silica with chlorine. Raw materials—chlorine and sodium silicate—are withdrawn directly from their own containers without handling or dilution. All chlorine used in the WT Silactor is available for the normal functions of chlorine, such as killing bacteria and algae, or for the oxidation of iron, manganese and other oxidizable material.

WT Silactor

DRY CHEMICAL FEEDERS

For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. The Types MO, MOF and MOI Dry Feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from 0.5 to 200 pounds per hour, depending upon the chemical used.

CONVENIENCE

W&T is represented in each of the 39 cities by a service staff prepared to give advice on the proper equipment for any chlorination problem.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

Taste and Odor Control in Small Water Plants

How the operator can solve problems caused by algae

By D. H. MATHESON
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THE difficulties attributable to algal growths constitute a perennial problem to the operators of treatment plants using surface waters as a source of supply. Each year these troubles must be overcome or endured. It is well to take stock, from time to time, of the preventive or ameliorative techniques that are available to minimize the plant difficulties and the public complaints arising from this recurrent phenomenon. In this paper, the subject will be considered particularly from the point of view of the small-plant operator who does not have expert technical advice at his immediate disposal, but who is expected, nevertheless, to know at least the possible courses of treatment that may be applicable to his situation.

The operator of a plant subject to algae troubles should make an effort to acquire some knowledge of these organisms. Of the many hundreds of algae species that occur in appreciable numbers in natural waters, comparatively few—perhaps a dozen or a score, at most—are regular causes of treatment plant difficulties. It is possible to learn to identify these with only a little training, as one learns to recognize the common wild plants and animals of the microscopic world. Simple counting methods can be used to indicate roughly whether the population density of an algal species is great enough to account for the operational difficulties that may be experienced.

Training of this nature is one of the most obvious advantages accruing from attendance at short schools for water works operators. It is highly desirable to know and recognize the causitive organisms rather than to treat blindly the symptoms observed in the plant. Some of the objectionable symptoms that are usually the effect of algae may occur in the complete absence of the organisms. It is evidently futile to take measures directed against algae if they are not the source of the difficulty.

The two most serious effects of algae in water treatment are interference with filtration and production of objectionable tastes and odors. The filter difficulties are generally due to a rather limited group of filter-blocking diatoms, although a few other organisms are occasionally present in sufficiently large numbers to be troublesome. The tastes and odors are caused by a wide variety of algae, the intensity and quality varying with the species concerned. Many organisms, especially the blue-green algae, produce more offensive odors when dead and decomposing than when alive.

Control of Algal Growth

Where the source of a water supply is a moderately sized body of stored water, either natural or artificial, direct chemical or biological interference in the cycles of growth of objectionable algae may often be advantageously undertaken. These control measures include reduction or limitation of the nutrient supply available to the organisms for their multiplication, the alteration of the physical conditions of the environment, such as the reduction of light intensity, and the planned destruction of algal populations by the use of algicidal chemicals.

The quantity of algae produced by a body of water—its productivity—depends on, among other things, the store of plant nutrients available to the organisms. These nutrients are contributed to the water from three main sources: the influent streams and the drainage from agricultural land; the addition of treated or untreated sewage; and the re-solution of mineralized nutrients from the decaying organic detritus on the bottom.

The access of nutrients in the influent streams and land drainage cannot be controlled unless the whole watershed can be managed and controlled as a unit. When this is possible, as it often is with watersheds in isolated, sparsely populated areas, significant limitation of plant food supplies may be achieved.

Domestic sewage contains large amounts of plant nutrients, particularly nitrogen and phosphorus, and may be expected to stimulate algal growths in the receiving waters. Ordinary sewage treatment does not remove appreciable quantities of these nutrients. Processes specifically designed to effect such reductions are of considerable interest at present.

Of the elements essential for algal growth, phosphorus is the one which is present in the waters in the smallest concentration, and which is therefore the one most likely to be depleted by algal growth, thus limiting the total algal crop. Sawyer[1] has recently pointed out that the phosphorus content of domestic sewage has probably doubled in the last 6 years, owing to the phenomenal growth in the use of synthetic-detergent compounds that contain much phosphate. It is quite likely, therefore, that sewage additions to water supplies will become increasingly more effective in causing large growths of algae than heretofore. Every care should be taken to minimize the access of nutrients through this agency.

Waters that are naturally high in nutrient level cannot be expected to show large decreases in plankton growth as the result of the removal of additional sources of nutrients.

In small presedimentation basins, control of the proliferation of algae may be obtained by restricting the entry of light. Covering such basins would no doubt be the ideal solution, but this is generally not economical for those of great size. The use of powdered activated carbon to reduce the penetration of light was instituted in the United States in 1939 and has attained wide popularity, especially throughout the midwestern states. The application of the carbon is quite simple; the quantities required are moderate and inexpensive; there is slight danger of ill effects through overtreatment; and some additional advantage may accrue through the adsorptive power of the carbon. There can be little doubt of the effectiveness of this treatment, as attested by its wide and continued use, but there is some uncertainty about the mechanism involved. It appears that the reduction of light intensity actually realized is not sufficient to account for the improvements noted in plant operation.

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Control of algae by the use of algicidal chemicals remains one of the standard methods of attacking this problem. Copper salts are still the only material widely employed, but research work is being prosecuted to find new, and perhaps more effective and specific, agents, especially in the field of organic chemicals. As the algae concerned are difficult to culture in the laboratory, it should not be too hard to discover some means of altering their natural environment to prevent their growth.

Chemical intervention in the biological system of the water should not be undertaken without due consideration of all the factors involved —the severity of the need, on the one hand, and the possible disadvantageous consequences, on the other. Treatment postponed too long may become inadvisable, owing to the deleterious effects of the release of a sizable quantity of organic matter after the destruction of a large algal population. A copper-resistant alga, generally one of the *Chlorophyceae*, frequently develops when a diatom population has been destroyed, and causes more difficulty than the original growth.

Copper sulfate is the salt most commonly used in algicidal treatments. Copper citrate, in the form of a proprietary preparation, appears to have some advantages under certain conditions, but there is little technical information available to demonstrate its superiority.

In relatively small basins, and, particularly, in filtered water reservoirs, chlorine has some value as an algicide and is effective against organisms that have a marked resistance to copper. The disadvantages include the difficulty in applying chlorine evenly to large bodies of water, the large amount required if the water has an appreciable chlorine demand, the rapid dechlorination that takes place when the water is exposed to sunlight, and the considerable danger of causing an increase in taste and odor through the formation of chloro compounds. Some of these deficiencies can be avoided with chloramine.

Copper and chlorine together are more effective than is either alone, and a combination of chlorine, copper, and ammonia, first used by Harold in England in 1934, has lately been employed by Smith at Richmond, Va., for the control of algae and other organisms in open service reservoirs and in the distribution system.[2]

In France, a novel process of "electrocution" is used for controlling the growth of algae in water applied to slow filters. An a-c field of approximately 90 v per inch is established between electrodes in a narrow channel through which water flows at approximately 1 fps. The algal cells are killed by the passage of the current through the water and do not multiply in the water on the filters. The process is used in one small municipal plant and has been proposed for a new one.

Algae and Filtration

When the source of supply is a river or a large lake, or when, for some reason, control of the algal growths in the water supply is not feasible, the purification plant must treat the algae-containing water as it comes to the plant. Removal of the algae by efficient coagulation and sedimentation is the obvious procedure, but it is attended with great difficulties.

The addition of coagulant frequently appears to make filtration more difficult, as the natural buoyancy of the algal cells prevents rapid sedimentation of the floc, and the filter load is increased. Many have reported that continued use of coagulants was practically impossible. Baylis and Gerstein[8] consider that certain algae add toughness to the flocculated particles deposited on the filter and thus tend to form a tenacious and impermeable mat on the sand surface.

Increasing the coagulant dose sometimes helps to overwhelm the buoyant effects of the algae with an enormous amount of floc. This method is obviously very expensive, especially when it is considered that water containing algae is usually very clear and requires little coagulant for clarification. It is not unusual to find that increasing the coagulant dose does little to improve filtration.

The addition of material such as clay to produce artificial turbidity aids in sedimentation by increasing the density of the floc and has been so used on several occasions. Baylis has offered the useful suggestion that, in waters like the Great Lakes, which are saturated with calcium bicarbonate, the addition of a small quantity of lime would cause the precipitation of an additional amount of calcium carbonate and economically provide a heavy material to weight the floc.

Activated carbon, when added before or with the coagulant, is effective in producing a more settleable floc, as has been demonstrated at Chicago.[9] Utilizing carbon in this manner for lengthening filter runs is an expensive procedure, but, as its use is required only for a comparatively short time during the year, the annual cost of water treatment is not unduly increased. The convenience of using a material that is already at hand, and for which feeding and handling equipment is already provided, makes it preferable to clay as a coagulant aid.

The improved coagulation that silica sols provide under certain circumstances has been used to a limited extent in attempts to remove algae.

The heavier floc produced by coagulation with iron salts makes these materials attractive in coagulating waters containing algae. Where plant-scale experiments have been performed, the advantages of iron coagulation have usually not been great, however, and have been overbalanced by the additional cost and the difficulties in handling and application. Alum has ultimately been found preferable as a coagulant.

The use of copper sulfate applied with coagulants is frequently mentioned as a means of improving filter operation. With motile organisms or those that tend to disintegrate when killed, the treatment appears to be effective, but, with diatoms, the dead cells do not seem to be removed by coagulation any better than do the living.

Prechlorination generally appears to be the most effective method of aiding coagulation in the presence of algae, particularly when the organisms are susceptible to disintegration by the chlorine. At Windsor, Ont., short filter runs caused by diatoms were much improved by prechlorination, especially when a free chlorine residual was produced.

Algae-containing waters that are to be treated on slow filters are frequently passed through coarse rapid filters first, to remove the greater portion of the algal load. In England, a unique process of microscreening has been developed commercially to pretreat these waters, in place of the bulkier roughing filters.[4] The screening membrane, a stainless steel fabric with apertures as small as 35 μ, is mounted on a continuously rotating drum, through which the water flows. The screen is continuously washed with approximately 1 per cent of the treated water. The larger diatoms are almost completely filtered out, and the overall removal is better when the water contains large amounts of suspended matter, because the heavy mat formed on the screen increases its effectiveness. When water supplies are free of color and turbidity and require

treatment only for removal of plankton, microstraining may possibly be used alone.

Sanchis has recently discussed the development of diatomite filters designed solely for the purpose of removing plankton from otherwise clear waters.

Operators of conventional rapid sand filters, when treating clear water containing only algae, find it best to use no coagulant. If the sand is not too coarse, most of the diatoms and other algae are removed, and if the turbidity of the raw water is not too high, preferably about 5 ppm, an acceptable quality of output can be maintained. Frequent short washes are sufficient to remove the algae from the filter, and the use of an above-normal quantity of wash water is a more economical way of removing the algae than is additional chemical treatment. This procedure has been used with satisfactory results at Hamilton, Ont., for more than 15 years. The turbidity of the filter effluent is kept below 1 ppm, a concentration that is not high enough to cause complaints. The wash water used during the algae season amounts to approximately 5 per cent, but, for short periods, it has risen as high as 10 per cent.

Tastes and Odors

Algae, living or dead, often most conspicuously affect water supplies by the production of tastes and odors. These vary in intensity and in quality from the not too objectionable fresh-vegetable and aromatic odors of many living algae to the highly offensive pigpen odor of decaying blue-green algae. As little is known about the exact nature of the chemical substances in the water that are responsible for the production of tastes and odors, progress in the development of ameliorative treatments has been on a purely empirical basis.

Chlorination in the usual moderate dosages generally has the effect of intensifying the odors of algae. Hale[8] attributed this fact to the freeing of the "essential oils" on the death and disintegration of algal cells. Some organisms liberate substances that, on chlorination, produce tastes highly medicated in character and practically indistinguishable from chlorophenol derived from industrial wastes.

From the standpoint of palatability, disinfection of water with chloramine is desirable because it minimizes the intensification of odors and, in general, aids in the removal of the odorous substances by activated carbon.

Superchlorination is effective against algal tastes and odors in varying degrees, depending on the algal species, the chemical properties of the water, and the peculiarities of the individual treatment plant. Superchlorination is particularly effective against the odor of *Synura*. The odors of diatoms, *Anabaena*, and *Dinobryon* are reduced, especially on long contact, but are not completely removed. Superchlorination requires much more careful chemical control for its successful operation than other treatments do, and it may produce highly odorous nitrogen trichloride in waters containing a large quantity of albuminoid ammonia.

Chlorine dioxide is now widely used for the control of tastes and odors and is very effective in removing chlorophenolic odors of industrial origin. Removal of strictly algal odors is accomplished with greater difficulty and by substantially higher dosages. Chlorine dioxide is the most effective treatment for removing the odors attributed to actinomycetes.

Ozone is the strongest oxidant commercially available for water treatment plants. It has attained its widest use in France, where a total of more than 160 mgd is ozonated. It is used there primarily for its bactericidal properties, but its oxidizing power for color and odor is recognized. The large ozonation plant at Philadelphia was designed primarily for taste and odor reduction, as, in the limited detention period possible, it was not feasible to control treatment by free residual chlorination. Ozone effected similar oxidation after a few minutes of detention. Ozonation requires much more expensive equipment than chlorination, a considerable deterrent to its use in the United States and Canada, where there is no strong aversion to the employment of chlorine. Ozone, however, completely avoids the danger of intensifying odors by the production of chlorinated compounds.

No method of taste and odor removal has attained widespread acceptance as rapidly as activated carbon. This treatment has outstanding advantages over chemical methods. It is effective, at economically justifiable dosages, against producing tastes and odors. Thus, it is not necessary to determine the exact cause and source of the offending material before treatment can be prescribed, whereas other methods may be applicable only to a limited class of substances. Carbon is simple and easy to apply. Although dosages of 2-5 ppm are usually effective, enormously greater amounts can be applied without danger of causing serious harm. And by no means the least of its advantages is the fact that its use appears to meet with the water consumers' approval, which is seldom accorded to other chemicals.

The principal problem in the use of activated carbon is the determination of the most economical dose. Sometimes very large doses are required, amounting even to 100 ppm, but these may be justified because the need for such treatment is usually of short duration. The efficiency of carbon treatment depends upon a number of factors. Adsorption is generally poorer at a higher pH. Chlorination may aid or hinder adsorption, depending on the nature of the odorous substance, and carbon is usually more effective with chloramine than with chlorine. In filtration plants, carbon may be used before coagulation, in which event coagulation may be improved and the sludge accumulating in the sedimentation basins stabilized. Carbon may also be added after coagulation, giving the floc an opportunity to remove some of the offending material first. Suspended carbon carried to the filters is very effective in the adsorption of odors, although some shortening of runs may occur.

Limited use is made of activated carbon in water where no filtration is provided. At several places in the United States where impounding reservoirs or small lakes have been heavily infested with algae, copper and carbon were used to remove the growth without producing objectionable tastes. In Winnipeg, Man., up to 2.5 ppm has been used in service reservoirs without causing difficulties, although higher doses are noticeable to the consumer.

Conclusion

The regular seasonal pulses of algae may cause serious difficulties in the operation of water purification plants. Although troubles may be unavoidable, they should not be considered insuperable. The battle against algae can be joined at several points.

The concentration of algae in the incoming water may be lowered by avoiding unnecessary fertilization of the supply, or by interfering with the multiplication of the organisms by physical or chemical means. Once in the plant, the algae can be re-

moved by improving the efficiency of coagulation. Microscreening offers interesting possibilities. Filtration without coagulation, and with the abundant use of wash water, is a cheap and effective procedure when applicable. A variety of treatments to combat offensive tastes and odors are available. These range from the powerful oxidants designed to destroy the odorous materials chemically to adsorbent carbons that remove the offending substances physically.

The deleterious effects of algae can be overcome. It is more often a question, depending on the severity of the conditions, of what expenditure is justified.

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Methyl Purple vs Methyl Orange In Alkalinity Titrations

By RALPH W. FREY

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RECENTLY there has come on the market an indicator known as methyl purple, with suggestions that it might be substituted to advantage for methyl orange in alkalinity titrations.

Most chemists know of the unsatisfactory behavior of methyl orange as an indicator. Its use frequently creates a desire for something that gives sharper and more contrasting color changes; requires less time; does not involve so much indecision and whose results are not so dependent upon the moods and color-consciousness of the individual.

Table I

METHYL PURPLE VS METHYL ORANGE

(River and Branch Waters)

Station	Collection Date	Kind	Alkalinity-ppm Methyl Purple(1)	Alkalinity-ppm Methyl Orange(1)
1	1/26/50	grab	15	19
2	"	"	17	21
3	"	"	51	56
4	"	"	45	50
5	"	"	41	41
6	"	"	60	59
1	12/14/50	"	21	22
2	"	"	21	23
3	"	"	58	59
4	"	"	26	29
5	"	"	29	31
6	"	"	31	33
11	11/21/50	"	10	11
15	"	"	12	14
16	"	"	18	18
17	"	"	17	18

(1)—With 4 drops of phenolphthalein.

Standard Methods for the Examination of Water and Sewage, 9th Edition, American Public Health Association, specify under "Alkalinity of Water" and also "Alkalinity of Sewage" the use of methyl orange, *or its equivalent.* Appreciating the opportunity that methyl purple might offer in replacing methyl orange in the alkalinity determination procedure strictly comparable titrations of sewage, chiefly sanitary, and of non-potable waters were made with these two indicators.

The results here presented need no elaboration. The end-point carried to a distinct purple with methyl purple is pleasingly sharp and far superior to that of methyl orange. The figures given show definitely that methyl purple can be substituted for methyl orange, a substitution that will prove most gratifying.

Table II

METHYL PURPLE VS METHYL ORANGE

(Sewage Treatment Plant No. 1)

Sewage	Collection Date	Kind	Alkalinity-ppm Methyl Purple(1)	Alkalinity-ppm Methyl Orange(1)
Raw	11/12/50	24-hr.	96	92
Primary	"	"	102	98
Final	"	"	96	96
Raw	11/16/50	24-hr.	140	140
Primary	"	"	126	128
Final	"	"	116	114
Raw	11/19/50	24-hr.	124	128
Primary	"	"	146	140
Final	"	"	144	152
Raw	11/23/50	24-hr.	120	124
Primary	"	"	142	144
Final	"	"	104	106
Raw	11/26/50	24-hr.	84	80
Primary	"	"	88	84
Final	"	"	88	86
Sewage Treatment Plant No. 2				
Raw	11/13/50	grab	184	188
Primary	"	"	204	216
T.F.E.	"	"	168	172
Final	"	"	140	140
Raw	11/17/50	"	152	152
Primary	"	"	212	220
T.F.E.	"	"	140	132
Final	"	"	136	128

(1)—With 4 drops of phenolphthalein.
T.F.E.—Trickling Filter Effluent.

Table III

METHYL PURPLE VS METHYL ORANGE

(Aged Sewage[1] - Treatment Plant No. 1)

Sewage	Collection Date	Kind	Alkalinity-ppm Methyl Purple(2)	Alkalinity-ppm Methyl Orange(2)
Raw	12/ 2/50	24-hr.	116	114
Primary	"	"	94	98
Final	"	"	88	90
Raw	12/ 5/50	"	98	94
Primary	"	"	104	98
Final	"	"	108	102
Raw	11/30/50	"	122	116
Primary	"	"	120	114
Final	"	"	120	116

(1)—Aged at 22°-26°C in open jar, then made to original volume with distilled water. First two groups aged 48 hrs.; last group aged 72 hrs.
(2)—With 4 drops of phenolphthalein.

The Control of Corrosion

By ROBERT SPURR WESTON
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EVER since metal pipes have been used for conveying, and tanks and other structures for storing or moving water, their protection against corrosion has been an important problem.

What is corrosion? Broadly defined, it is the chemical action of certain external agencies which cause the deterioration of metal. Confining attention to iron, there are several established facts regarding it which are so well known that they need be only summarized.

When corrosion is in mind, one thinks of red or rusty water, stained porcelain fixtures, stained clothes from the laundry, and leaking services. Serious as these are, far more so are the economic losses due to the flow impeding products formed on the walls of pipes of water systems, with the consequent reduction in carrying capacity, and the scaling up and pitting of steam boilers. For example, a cast iron pipe having a life of 100 years under normal conditions may lose over half of its carrying capacity in 25 years because of increased friction and decreased area of cross-section due to tuberculation or other forms of rusting. Incrustation is, therefore, more important than loss of metal, for the metal dissolved from the pipe is but a small part of the mass of iron compounds, often containing organic and mineral matter, which accumulates on the corroded surface of the attacked metal.

Because chemically pure waters are the ones which are most frequently corrosive, the troubles due to corrosion have increased as better and better waters have been supplied. For example, a colored surface water will often deposit a protective coating of organic matter on the surfaces of pipes and retard corrosion; yet, when this same organic matter is removed by coagulation and filtration, the water becomes clear, is often not alkaline, and usually is so corrosive that corrective treatment is required.

Oxygen and Hydrogen—The Corrosion Team

The active agent in the corrosion of metals is oxygen, but this element would be almost powerless by itself were it not for the action of what are known as acid or hydrogen ions. Everyone knows that water is composed of two atoms of hydrogen (H) and one of oxygen (H_2O), but, according to the well-established electro-chemical theory, an extremely small fraction of a water is dissociated into H (hydrogen) and OH (hydroxyl). The familiar term "pH value" is used to indicate the concentration of these H ions. When the concentrations of H and OH ions are equal, a water is neutral and contains one ten-millionth (0.0000001) of a gram equivalent of both ions per liter.

The scale of pH values may be compared with the fine adjustment on an engineer's transit, or a vernier on a machinist's calipers. Some of the values are as shown in above table.

The interesting and significant part about this scale of pH values is the fact that the seemingly small change of only 1 in pH value actually represents acidity or alkalinity 10 times that of the higher or lower pH value. In other words, a solution with pH value of 4 is 100 times more acidic than a solution with a pH value of 6.

How refined is the scale of pH values may be realized from knowing that the pH of a good ground water containing 50 parts per million of carbon dioxide gas may be less than 6.0; of ordinary New England river waters, 6.2 to 7.6; of alum-treated filtered waters, 5.4 to 6.6; of a water of this region just saturated with calcium carbonate (chalk), about 8.4; and of a highly alkaline water, 11.0.

The pH value is so easy to determine that it is used for explanation by many operators, some of whom tend to place too much reliance upon it. Generally it determines the *rate* of corrosion rather than the amount. The *amount* is contingent largely upon the quantity of oxygen present. Theoretically, the acid ion (H) attacks the metallic iron; then the oxygen combines with the iron, releasing the H ion for a further attack, and the cycle moves on. Consequently, the lower the pH value the higher the acid concentration and consequent *rate* of solution.

	Concentration (Grams Equivalent Per Liter)	pH Value
Acid hydrogen (H) ions predominate in this zone above the neutral line	1.0	0
	0.01	2
	0.0001	4
	0.000001	6
NEUTRAL CONDITION	0.0000001	7
	0.000001	8
	0.00001	9
	0.0001	10
Alkaline (OH) ions predominate in this zone below the neutral line	0.001	11
	1.0	14

Signs of Corrosion

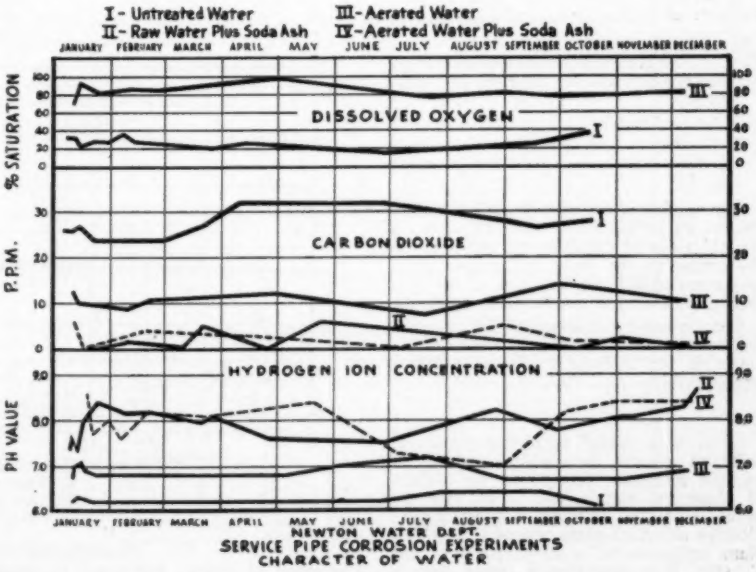
The well-known signs of corrosion are the black or green ferrous (unoxidized) rust formed next to the metal, and the reddish brown ferric (oxidized) rust at the surface, with mixtures of the two between. Some coatings are dense and retard corrosion. Some are porous and slow it down but little. Because the susceptibilities to corrosion vary greatly over the surface of the metal, the action is frequently localized in the form of tubercles, as, for example, where a protective coating inside a pipe is impenetrable except in spots. The dislodgment of rust coatings or tubercles causes the well-known "red water" troubles.

In New England, there are some well waters low in pH value, and corrosive, but which form no coatings of rust inside the pipes, and come clear at the taps. Usually these contain iron in solution and there is a streak of red rust on tub or bowl where the dissolved iron oxidizes and collects.

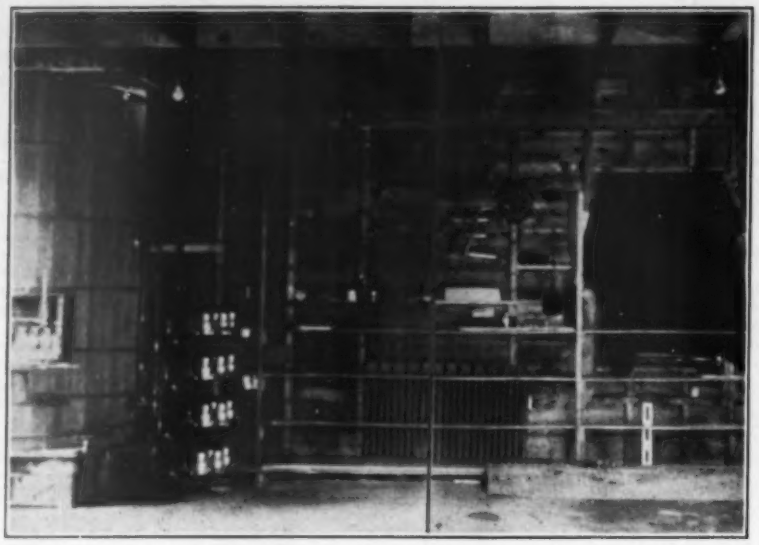
The pH value and oxygen content are not the only factors in corrosion. In natural waters the organic contents, or sulfates, carbonates, chlorides, and other salts—of calcium and magnesium particularly—reduce or modify the corrosive action of waters or affect the protective treatment required. A good critical review of modern theoretical researches with references to the works of Baylis, Langelier, Enslow, Hale and others, has been recently given by Prof. Edward W. Moore[1] of the Harvard Graduate School of Engineering.

Correction and Control

Obviously, with acid waters containing oxygen,—and most of them do,—it is well to reduce the acidity or increase the alkalinity by the addition of an alkali. For this purpose two chemicals have been used extensively, namely: carbonate of soda (soda ash), and hydrated lime—Na_2CO_3 and $Ca(OH)_2$.


I - Untreated Water
II - Raw Water Plus Soda Ash
III - Aerated Water
IV - Aerated Water Plus Soda Ash
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER
% SATURATION
DISSOLVED OXYGEN
P.P.M.
CARBON DIOXIDE
PH VALUE
HYDROGEN ION CONCENTRATION
NEWTON WATER DEPT.
SERVICE PIPE CORROSION EXPERIMENTS
CHARACTER OF WATER

Experimental Data—Study of Water Treatment in Service Pipe Corrosion Tests for Newton, Mass.



Corrosion Study Installation of Various Service Pipes for Evaluating Anti-Corrosion Treatments at Newton, Mass.

Soda-Ash

When soda ash is used, little or no insoluble coating, except iron hydroxide, is formed on the iron, and when it is added to a colored surface water, the color may be increased which is objectionable. Nevertheless it has its uses. A case at point is that of Newton, Mass.

Before 1928, the city of Newton was supplied with water from wells. Later on, conditions demanded the construction of infiltration basins which are filled from the Charles River and which are used to increase the supply from the wells. The effect was an increase in the amount of oxygen and a decrease in the amount of carbon dioxide, with resulting increase in corrosion. Brass pipe was short-lived and there were blue stains on bowls and baths where copper pipe was used. Iron, of course, was attacked also.

A series of experiments[2] were planned and carried on for about a year, using

(a) Untreated water;
(b) The regular supply treated with enough sodium carbonate to raise the pH value to 8.0;
(c) Aerated water;
(d) Aerated water treated with enough sodium carbonate to raise the pH value to 8.0.

The results showed that by adding enough sodium carbonate (soda ash) to maintain the pH value of the delivered water at 7.6 the action on the brass and copper pipes was arrested and the corrosion of the iron piping came within the limits of tolerance.

Consideration was afterward given to the addition of lime, but it was not adopted because of the increase in hardness which would result.

Character of Raw Water and Effects of Treatment With Soda Ash, Newton, Mass.

Results of Analysis (Parts Per Million)

Constituent	PUMPING STATION Untreated	Treated	Supply Yard
Turbidity	0.	0.	0.
Color	2.	5.	5.
Alkalinity	26.0	74.0	72.0
Hardness	29.9	29.9	31.2
pH value	6.2	7.8	7.6
Iron	0.08	0.10	0.08
Carbon dioxide	25.0	4.0	4.1
Dissolved oxygen % saturated	33.8	.....	.....

Lime

Lime, when added to certain waters in sufficient amount, produces a coating of calcium carbonate (chalk) on the surface of pipes and metals, and is an effective agent. However, ordinary soft local waters dissolve about 30 parts per million of calcium carbonate at a temperature of 20° C. (68° F.); consequently, when lime is added to these waters in sufficient amount, the hardness of the water is appreciably increased, sometimes to an objectionable degree. To saturate these waters with calcium carbonate, it is necessary to raise the pH value to about 8.4, with a consequent noticeable increase in hardness.

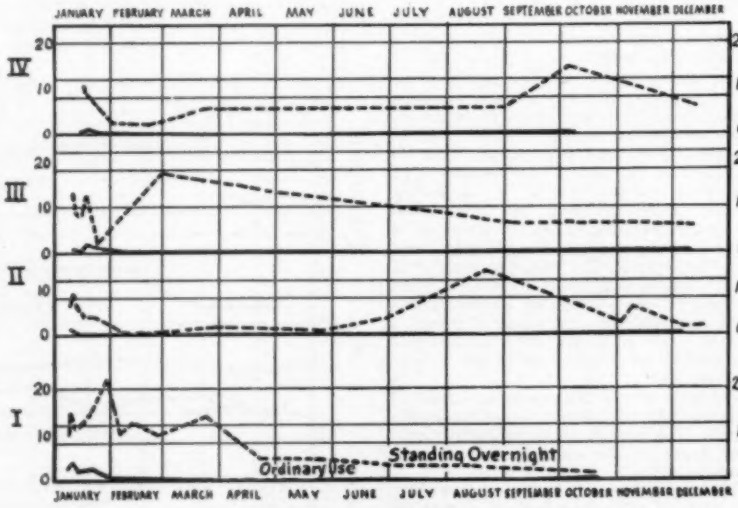
In practice, one adds enough lime to keep the pH value below 8.4 in order to avoid incrusted meter parts and piping, and above about 7.8 to keep the consumers from ringing the superintendent's telephone to complain of red water. Under these compromising conditions, there is necessarily some corrosion but usually it may be controlled by adequate flushing of the mains.

Silicate of Soda

In some cases sodium silicate (water glass) is added also, say, in small amounts with the lime, or say once a week or ten days, in larger amounts. The calcium silicate, so formed, is less soluble than the calcium carbonate and helps to maintain a protective coating on the metal. This is the practice at North Attleboro, Mass., and was the practice at Winchester, Mass., until a change was made by substituting sodium hexametaphosphate, which is more generally known as "Calgon." Concerning "Calgon" treatment more is to be said later.

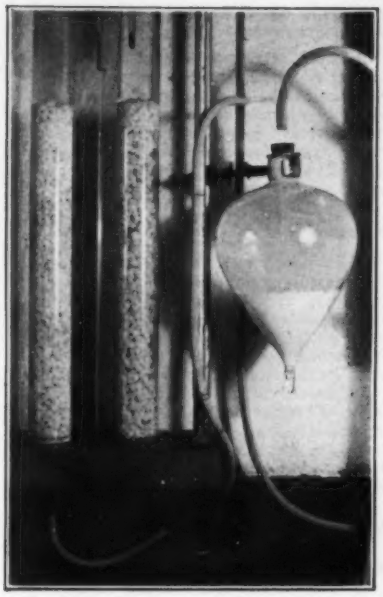
The object of the addition of lime or any other chemical is to limit the attack of the water by holding the products of corrosion at the boundary surface of the metal in the form of a thin layer. Rust alone is too porous for protection, but rust plus calcium carbonate (chalk) is generally effective. Moore[1] has referred to the work of Langelier who devised the formula for establishing the equilibrium of any water with calcium carbonate, and consequently the proper dose thereof; also that of Enslow who devised a convenient apparatus for determining continuously the widely varying degree of saturation for waters ranging in hardness or alkalinity from less than 10 to nearly 1,000 parts per million.

This apparatus saves the time of chemists in making the so-called marble test, devised by C. P. Hoover, or in arriving at the Langelier index of corrosivity, which, as stated, determines the proper dose of lime.


JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER
IV
III
II
I
Ordinary Use
Standing Overnight
EXPERIMENT I Untreated Water
" II Raw Water Plus Soda Ash (P.H. 8.2)
" III Aerated Water
" IV Aerated Water Plus Soda Ash (P.H. 8.2)

Experimental Data, Newton, Mass.

The effect of various treatments in subduing attack on black iron pipe reveals ppm. iron dissolved by flowing water as compared with water standing in the pipes overnight and recorded by dashed lines.



The Enslow Continuous Stability and Corrosivity Indicator

The simple and inexpensive Enslow Corrosivity Indicator is described in Reference and Data Numbers of WATER WORKS AND SEWERAGE for 1941 and 1942.

It was soon found, however, that the effects of lime treatment alone did not reach the dead ends of the system until after a considerable period, and frequently not until an undesirable accumulation of deposit had occurred near the point of application of chemical.

This is illustrated by the experience at Wakefield, R. I. where an old works has been supplying water to industrial and mercantile villages, summer and pleasure resorts over a wide area. The colored raw water is from surface sources, and for about fifty years was supplied untreated; but, while there was an accumulation of organic matter in the mains, few complaints were aroused because of corrosion.

In 1930, the works postponed the construction of a water purification plant by adding chemicals to the inlet of the lowest reservoir in the system and using it as a coagulating and clarifying basin. This was a beneficial but temporary practice, and, in 1940, after a study of the possibilities of ground water supply, pressure filters were installed and the water was treated with alum, with no provision for flocculation. The resulting acid water (usually clear and low in color) caused dislodgements and corrosion. Lime was added, sometimes in excess, and this accumulation, with the older ones, was often dislodged and caused complaint.

Experiences with "Calgon" Treatment

To delay the carbonate precipitation, and to avoid the addition of an excess of lime, the application of sodium hexametaphosphate was resorted to.

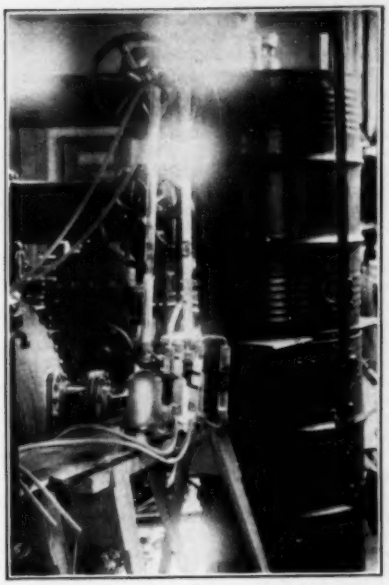
This chemical, sold under the trade name of "Calgon," was first used to delay or inhibit the after-precipitation of calcium carbonate in water softening; and, later, to cause the gradual coating of the out-lying parts of the distribution system, and to reduce accumulations near the source of supply. It was also believed that the phosphate would not only prevent excessive deposition, but, when added alone, would inhibit corrosion because of its power to form a thin protective film (said to be a molecule thick) on the surface of metal with waters having pH values on the acid side of neutrality.

The writer's first experience with this chemical was at Fairhaven, Mass.[8] Here, the raw water from wells was slightly corrosive and contained enough iron to form deposits, but too little to warrant its removal by the usual methods. Here, the metaphosphate has been employed successfully. It has controlled corrosion and has kept the iron in suspension, even at the dead ends.

Early in 1941 it was decided at Wakefield, R. I., to apply metaphosphate and to gradually reduce the dose of lime at the same time. Application of metaphosphate was begun on May 6th. Application of lime to the filter effluent was gradually reduced, and was discontinued on August 16th. Metaphosphate was applied first at the rate of 4 ppm., and later at the rate of 2 ppm. While it may be too early to give a true picture of the results, they have been satisfactory. The older chalky deposits have been removed from most of the system. "Red water" troubles have nearly ceased, and flushing of the mains is attended with less and less sediment. The present indications are that a lower dose of metaphosphate will suffice.

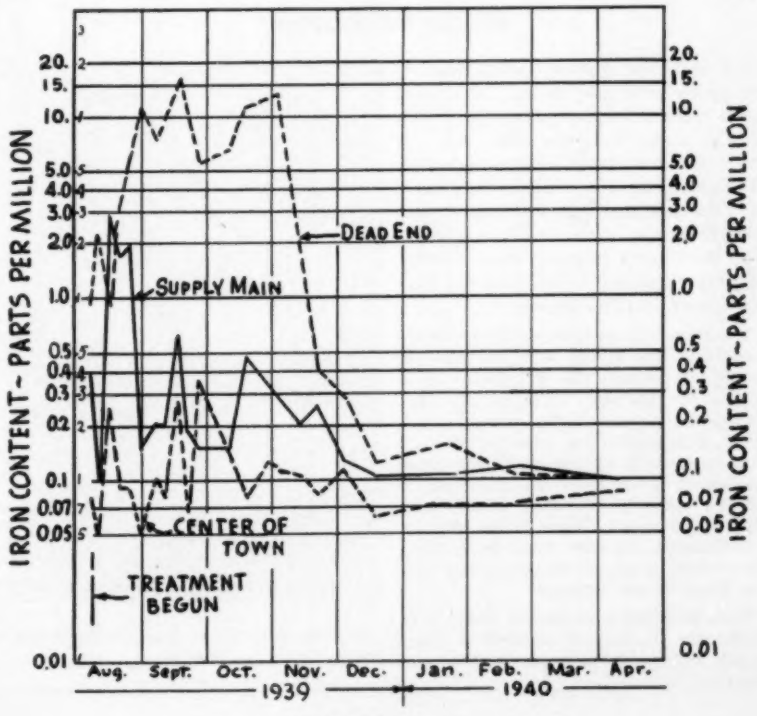
In the 21 months of operation, by gradually reducing the lime dosage, the pH value of the delivered water has been reduced from 8.8 to 5.2 at the filters and 6.0 at a point on a branch line four miles away.

Experience with metaphosphate is still too limited, and waters vary so much in their requirements, that it is not yet possible to generalize with accuracy regarding its effects. It is found that it is an inhibitant when present at a concentration of a few parts per million, even when the pH value is low. It protects iron and copper when the pH is high. On the other hand, it behaves differently when in solution containing from 0.1 to 1.0 per cent or more. Here it forms complexes with calcium, magnesium, iron, aluminum, zinc and tin.



Experimental Installation at Fairhaven, Mass.
For studying effect of "Calgon" and other corrective treatments.

At Wakefield, R. I., the soldered joints in the copper feed tank, used to apply the chemical, were dissolved rapidly, as was the galvanizing on a steel drum used to store the solution. Apparently, welded black iron,



Fairhaven Results
The effects of "Calgon" Treatment.

stainless steel, rubber and glass are the best materials for use in contact with strong solutions of hexametaphosphate.

Even the apparent protection given iron pipes when waters of low pH value, containing one or two parts per million of metaphosphate, are passed through them is somewhat in doubt. This statement is made because the chemical is so good a dispersant of iron and other metals that it would prevent the usual red stains from appearing on basins and bowls.

A reading of the report of the round table discussion on corrosion control at the New Orleans meeting of the American Water Works Association in 1938,[4] followed by a reading of the Committee report[5] on the value of sodium hexametaphosphate in the control of difficulties due to corrosion in water systems, published four-and-a-half years later, will give one an idea of the varied and complex character of the problem.

With the above report is a contribution by Dr. F. E. Hale which warns one not to make the mistake of believing that hexametaphosphate prevents the corrosion of iron by soft waters of low pH value, even when the delivered water is of good appearance, free from red water and causes no increase in friction in the mains.

In this connection one must bear in mind the large amount of iron in the pipe system and the small amount in the treated water. In a works discharging 200 million gallons yearly containing 0.10 ppm. of iron dissolved from the mains, the weight of iron lost would amount to only 167 lbs. per annum while the amount of cast iron pipe in the distribution system might weigh from 20 to 30 million pounds, or even more. This does not mean that the possibility of leakage at nipples and joints should be dismissed as negligible or that solution of metal should not be watched. It probably does mean that a better condition than where tuberculation and incrustation with attendant loss in capacity occurs, and which the metaphosphate treatment minimizes or prevents.

Cathodic Protection

During the last few years many waterworks have resorted to electrolytic treatment designed to reverse the ordinary electrolytic action of water. To do this, electrodes are placed in standpipe or filter shell and current is passed from the positive electrode in the water to the negative electrode on the metal, with the result that instead of the corrosive H ion reaching the metal the non-corrosive alkaline OH ion takes its place.

This method, when applicable, is efficient and its cost of operation is low. The chief objection to it, in standpipes particularly, is the effect of ice, which often carries away the electrodes. Fortunately, however, the electrodes can be removed for a few weeks during the winter when corrosive action is lowest. Apparently the protection given the metal during the warmer months of the year is prolonged for a considerable period beyond the time of removal of the electrode.

Naturally, more trouble is experienced when this type of apparatus is used with surface waters than with ground waters, because the temperature of the latter rarely falls below 45° F. as compared with 34° F. for surface waters.

Cathodic protection can also counteract another type of electrolytic corrosion, sometimes called battery action. For example, where two metals, like copper and zinc, are in contact and immersed in water, the zinc goes into solution, an action which countercurrent, afforded by cathodic protection, would neutralize if properly controlled.

In General

In considering the control of corrosion, one must bear in mind that waters vary greatly in their characteristics and action. Consequently, it is extremely difficult to prescribe the best remedy for corrosion control without some actual tests, like those made by the city of Newton. For this purpose, makes of pipe are subjected to the action of treated and untreated waters under conditions of ordinary use and standing overnight for a sufficiently long period to determine what is best for control of corrosion.

References

(1) Corrosion Control. Prof. Edward W. Moore, *J.N.E.W.W.A.* **55** (1941), 265.

(2) Experiments on the Newton Water and Treatments for the Control of Corrosion. F. W. Gilcreas, *J.N.E.W.W.A.* **48** (1934), 105.

(3) Corrosion Control by Metaphosphate. H. T. Gidley and R. S. Weston, *J.A.W.W.A.* **32** (1940), 1484.

(4) Corrosion Control. Wiggin, Norcom, Glace et als. *J.A.W.W.A.* **30** (1938), 1342-87.

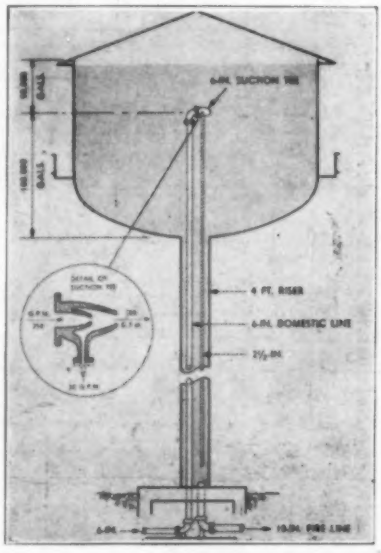
(5) Report of Committee on Water Conditioning Methods to Inhibit Corrosion. E. W. Moore, Chairman. *J.A.W.W.A.* **34** (1942), 1807-1828.

NOVEL SCHEME FOR PREVENTING TANK RISERS FROM FREEZING

Out at Grand Canyon, in Arizona, it gets pretty cold and during the winter season there is but little turnover in the elevated water tank, the chief duty of which is fire sprinkler service during the off resort season. To avoid the solid freeze-up of the tank riser during the low winter turnover period, Santa Fe Railway engineers developed a unique scheme of intermittently circulating water from the bottom upwards through the riser.

The scheme in question has been in successful use now during 15 winter seasons. Briefly, it involves the installation of a suction tee educator (Watson and McDaniel) on the end of the filling pipe. A 2½-in. drop suction line from the educator picks up water at the rate of 30 gpm. from the bottom of the riser and discharges it into the center of the tank to mix with the warmer water. While an ice shell of 2 in. thickness has been found in the riser, the circulating scheme has prevented further ice shell encroachment.

This information originated from G. L. Davenport, Jr., division engineer of water supply, Santa Fe Railway System, Los Angeles.



Schematic Sketch of Riser Recirculating System

"GOVERNMENT" WHITEWASHES

The following formula is commonly known as "Government Whitewash." It is used on lighthouses and other places exposed to the weather, and does not peel off.

Carefully slake one-half bushel (38 pounds) of good quicklime, covering during the process to keep the steam in. Strain the paste while still thick through wire fly screen cloth and add about four gallons of water. While stirring vigorously, pour into the lime mixture a solution made by first dissolving 12 pounds of salt and 6 ounces of alum in about 4 gallons of hot water. Then add one quart of molasses and thin with water to suit requirements.

Another method is:

Using one-half bushel (38 pounds) of good unslaked lime, slake with boiling water and keep covered during the process to keep the steam in. Strain the liquid through a sieve fine enough to retain all unslaked lumps. Dissolve a peck of clean salt in a little water and add to the solution. Boil to a thin paste three pounds of rice and put into the mixture, while hot, and one pound of glue, previously melted over a fire. Add one-half pound of whiting. Mix well and then add 5 gallons of hot water, stirring well. Cover closely and let stand several days.

If the whitewash can be applied when hot, it will go on better and last longer. Coloring matter may be used to vary the tint to suit the taste.

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

No. N Fraction	Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
1/8	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
1/4	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
3/8	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
1/2	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
5/8	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8297	.3712
3/4	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
7/8	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1 1/8	1.125	1.266	1.061	.9940
1 1/4	1.25	1.563	1.118	1.227
1 3/8	1.375	1.891	1.175	1.485
1 1/2	1.50	2.250	1.225	1.767
1 5/8	1.625	2.641	1.275	2.074
1 3/4	1.75	3.063	1.323	2.405
1 7/8	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2 1/8	2.125	4.516	1.458	3.547
2 1/4	2.25	5.063	1.500	3.976
2 3/8	2.375	5.641	1.541	4.430
2 1/2	2.50	6.250	1.581	4.909
2 5/8	2.625	6.891	1.620	5.412
2 3/4	2.75	7.563	1.658	5.940
2 7/8	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3 1/8	3.125	9.766	1.768	7.670
3 1/4	3.25	10.56	1.803	8.296
3 3/8	3.375	11.39	1.837	8.946
3 1/2	3.50	12.25	1.871	9.621
3 5/8	3.625	13.14	1.904	10.32
3 3/4	3.75	14.06	1.937	11.04
3 7/8	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4 1/8	4.125	17.02	2.031	13.36
4 1/4	4.25	18.06	2.062	14.19
4 3/8	4.375	19.14	2.092	15.03
4 1/2	4.50	20.25	2.121	15.90
4 5/8	4.625	21.39	2.151	16.80
4 3/4	4.73	22.56	2.180	17.72
4 7/8	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5 1/4	5.25	27.56	2.291	21.65
5 1/2	5.50	30.25	2.345	23.76
5 3/4	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6 1/4	6.25	39.06	2.500	30.68
6 1/2	6.50	42.25	2.550	33.18
6 3/4	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7 1/4	7.25	52.56	2.693	41.28
7 1/2	7.50	56.25	2.739	44.18
7 3/4	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8 1/4	8.25	68.06	2.872	53.46
8 1/2	8.50	72.25	2.916	56.75
8 3/4	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9 1/4	9.25	85.56	3.041	67.20
9 1/2	9.50	90.25	3.082	70.88
9 3/4	9.75	95.06	3.123	74.66

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
10	100	3.162	78.54
11	121	3.317	95.03
12	144	3.464	113.1
13	169	3.606	132.7
14	196	3.742	153.9
15	225	3.873	176.7
16	256	4.000	201.1
17	289	4.123	227.0
18	324	4.243	254.5
19	361	4.359	283.5
20	400	4.472	314.2
21	441	4.583	346.4
22	484	4.690	380.1
23	529	4.796	415.5
24	576	4.899	452.4
25	625	5.000	490.9
26	676	5.099	530.9
27	729	5.196	572.6
28	784	5.292	615.8
29	841	5.385	660.5
30	900	5.477	706.9
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16583
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
...	.....	....	.....
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...	.....	....	.....

Principles of Handling Chlorine

By V. W. LANGWORTHY
Research Chemist, The Chlorine Institute, Inc., New York, N.Y.

I—Chlorine Packages

LIQUID chlorine was introduced as an article of commerce in 1909, and developments in its handling and application have progressed steadily. Caution has been the watchword, with careful attention being paid to the lessons learned through numerous valuable, and sometimes bitter, experiences.

It is the purpose of this series to delineate, in a practical way, the present day handling techniques which use equipment evolved from cautious advancement in the art of chlorination.

Chlorine Packing Units

Anhydrous liquid chlorine is available in packages of several sizes, all of which are pressure vessels of steel construction and are equipped with safety devices. Loaded packages have about 12 per cent gas space at 68° F. to allow expansion of the liquid contents when exposed to higher temperatures. Internal inspection of returned packages is routine: outlet valves are removed and overhauled after each trip and all packages are pressure-tested at regular intervals.

Chlorine Cylinders

Consumers of chlorine used for sanitation are familiar with 100 lb., 105 lb. and 150 lb. packages, properly refererred to as cylinders. The Interstate Commerce Commission specification number, serial number, producer's insignia, date of last hydrostatic pressure test and the tare weight are stamped into the shoulder of each cylinder.

Cylinder valves have brass bodies and Monel metal stems; these valves have been standardized by The Chlorine Institute, Inc. Each chlorine cylinder valve is equipped with a fusible plug safety device designed to melt between 158° F. and 165° F. (Fig. 1).

Chlorine cylinders, empty or full, should never be dropped or permitted to strike each other with any force.

Ton Containers

Liquid chlorine is also available in one-ton packages, properly referred to as ton containers. The Interstate Commerce Commission specification number, serial number, producer's insignia, date of last hydrostatic pressure test, water capacity and tare weight appear on each container.

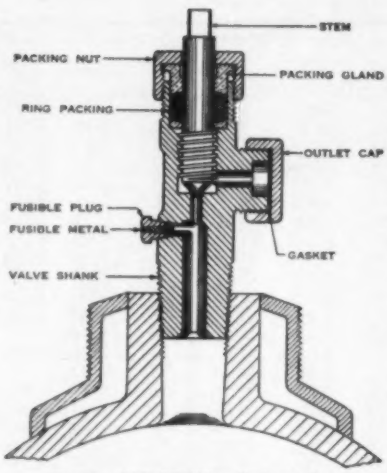

Fig. 1—CHLORINE cylinder valve
This is the Chlorine Institute standard cylinder valve with screwed type fusible metal plug. There is also a standard poured type plug.

Each ton container is equipped with two Chlorine Institute standard ton container valves (Fig. 2). Valves for ton containers are *similar* to the valves used in cylinders, but they differ in that ton container valves have a larger internal hole and *do not* have a fusible plug safety device (Fig. 3). Safety precautions for ton containers are observed by utilizing six fusible plugs per container. Three plugs are located in each end of a container, spaced 120° apart. The fusible metal has been designed to soften or melt at a temperature between 158° F. and 165° F.

Chlorine containers, empty or full, should never be dropped or permitted to strike each other with any force.

Tank Cars

The largest common chlorine shipping packages are single unit railroad tank cars of three different capacities: 16, 30 and 55 tons. These consist of a steel tank, four inches of cork insulation and an outer steel shell. Four angle valves are located in a dome centered on the top of the car. The valves are constructed of forged steel, with Monel stems and seats (Fig. 4). Outlet threads of the valves are 1-inch female standard tapered pipe threads. Tank cars have a spring loaded safety valve located at the center of the dome. This device is gas tight at or below 180 lbs. pressure (gauge), and pops at 225 lbs.

Liquid chlorine is unloaded through the two angle valves located on the axial center line of the tank; eduction pipes leading to these valves are fitted with rising ball check valves designed to shut when the rate of flow of liquid chlorine is 7,000 to 8,000 pounds per hour.

Gaseous chlorine may be unloaded through two angle valves located at right angles to the length of the car (on 55 ton tank cars, one of these gas valves has been replaced with a second safety valve).

The U. S. Coast Guard has authorized the shipment of chlorine by tanks on barges especially designed for this service. A few producers make use of this means of conveying comparatively large quantities of liquid chlorine. This package has not been used in the sanitation field.

Handling Chlorine Cylinders

(100, 105 and 150 pound capacity)

Transportation of full and empty cylinders usually is accomplished by

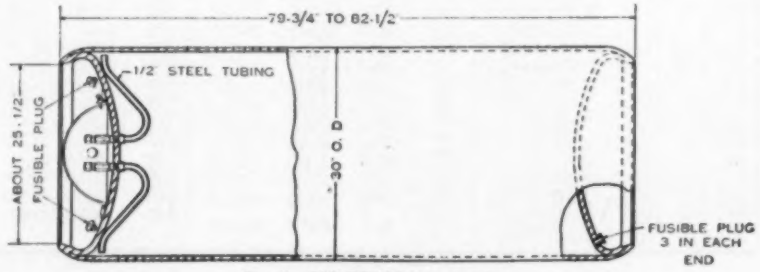

Fig. 2—CHLORINE ton container
The ton container is equipped with two valves connected to eduction pipes, and has three fusible metal plugs in each end.

truck or rail shipment. In the interests of safety, unloading docks should be at truck or car bed level. Manhandling of cylinders is dangerous and use of hand trucks is recommended. The use of a well-designed hand truck, properly balanced, preferably with a clamp support at least two-thirds of the way up the cylinder, is considerably more economical than the consequence of a possibly fatal mishap (Fig. 5).

A partial listing of firms offering hand trucks of this type is the following:

The Fairbanks Co.,
393 Lafayette St.,
New York 3, N. Y.

The Lansing Co.,
Lansing, Michigan.

Colson Corp.,
Elyria, Ohio.

Hamilton Truck and Caster Corp.,
Hamilton, Ohio.

Cylinders should be stored in a cool place, in an upright condition, away from dampness, ventilators, elevators and walkways. Valve protection caps should be kept in place until immediately before use. Never lift cylinders by the cap, and do not use a lifting magnet or sling in handling cylinders. Cylinders should be used in the order they are received, since it is possible for old valve packing to become dry enough to permit escape of chlorine gas. It is desirable to support cylinders securely during chlorine withdrawal.

Connection to the cylinder valve outlet may be made by either a clamp-and-adapter (Figs. 6A and 6B) or a union connector (Fig. 6C). In either case, inspect the inner surfaces of the joining parts and always remove old gaskets and foreign material. When a full cylinder is connected, a new gasket of standard material should be used. Standard gasket materials are 3% antimony lead, or Garlock 900 or equivalent.

Open cylinder valves slowly: one complete turn of the stem in a counter-clockwise (left hand) direction opens the valve sufficiently to permit maximum discharge. Do not use a wrench longer than 6 inches for operating a cylinder valve. Leaks may be detected by holding an ammonia moistened cloth near all connections. When this is done, the presence of chlorine will be evident if a white cloud (ammonium chloride) is formed (Fig. 7).

The practice of compounding cylinders (manifolding) to increase *gas* withdrawal rates entails increased caution when putting full cylinders in service. A good precaution to observe is a check of each outlet connection by partially opening and immediately closing the cylinder valve to insure that solid connections have been made.

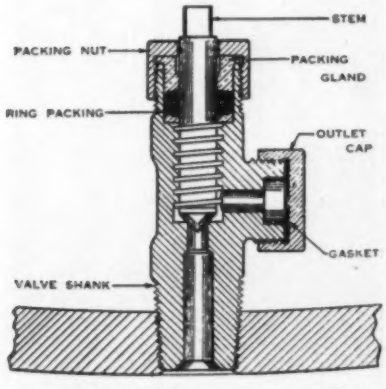

Fig. 3—CHLORINE ton container valve
This is the Chlorine Institute standard ton container valve; it has no fusible metal plug.

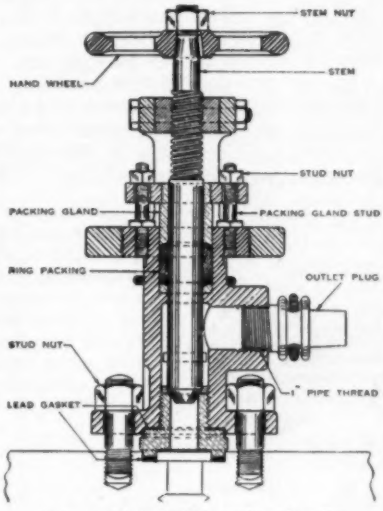

Fig. 4—CHLORINE angle valve for tank cars

Consumers removing *liquid* chlorine from cylinders are cautioned that manifolding cylinders for liquid chlorine withdrawal should NOT be attempted.

Handling Chlorine Containers

(2,000 pound capacity)

Transportation of full and empty ton containers usually is accomplished by rail. The ton multi unit railroad tank car has been developed to meet the needs of consumers using chlorine in excess of 30 tons per year. The car consists of an underframe on which are mounted 15 detachable containers, each containing 2,000 lbs. of liquid chlorine. The car is classified as a tank car and freight is charged only on the 15 tons of liquid chlorine. The empty containers on returning underframes travel on a freight free movement. It is possible in certain locations to obtain ton containers via truck delivery.

Fig. 5—HAND TRUCK for chlorine cylinders
Note rubber tires and strap to secure the cylinder during movement.

The advantages of using chlorine from ton containers are well known: less handling, connecting and disconnecting. The fact does exist, however, that ton containers are bulky to handle. They may be handled safely, provided adequate equipment is available for unloading, storing, using and re-loading empty containers.

Unloading full containers may be accomplished by means of a specially designed lifting clamp* (Fig. 8). The clamp is used in combination with a hoist on a trolley or a jib boom. Ton containers which must be trucked from the siding to the storage area should be placed on saddles on the truck and clamped down to prevent shifting and rolling. Cradles should also be provided in the storage area, with overhead hoisting equipment for transporting containers to and from the scale room (Fig. 9).

It is good practice to store ton containers in a cool place, away from dampness, ventilators, elevators and walkways. Containers should be stored on their sides, with valve protection hoods in place. Do not store chlorine containers in the vicinity of combustible or flammable materials.

As with chlorine cylinders, it is advisable to use full containers in the

*One source of supply for these clamps is Mansaver Industries, Inc., 3105 East St., New Haven, Conn.

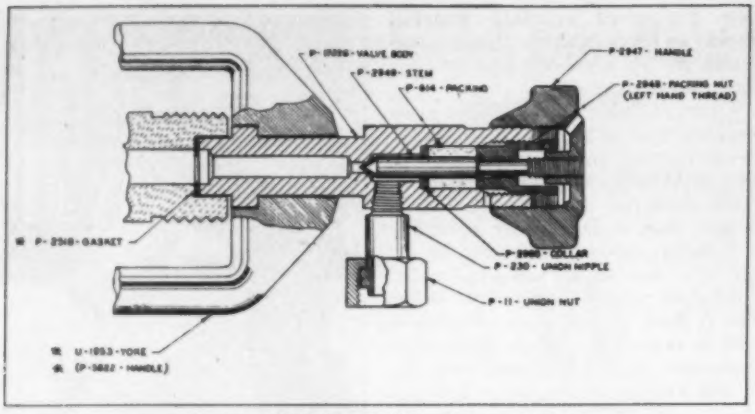

Fig. 6A—CYLINDER VALVE outlet connection
This is a clamp-and-adapter or yoke type connection of auxiliary valve to chlorine cylinder valve.

Fig. 6B—CONNECTION to cylinder valve
Note proper size of wrench (6-in. long) for tightening yoke clamp and operating cylinder valve.

order they are received. *Never* tamper with fusible plug safety devices.

Connection to the proper container valve outlet may be made either by a clamp and adaptor or a union connector. The proper valve depends on whether liquid or gaseous chlorine is to be withdrawn (Fig. 10). Placement of the container on scales must be such that the two valves are positioned vertically. Thus eduction pipes within the container will conduct liquid chlorine to the lower valve and gaseous chlorine to the upper valve.

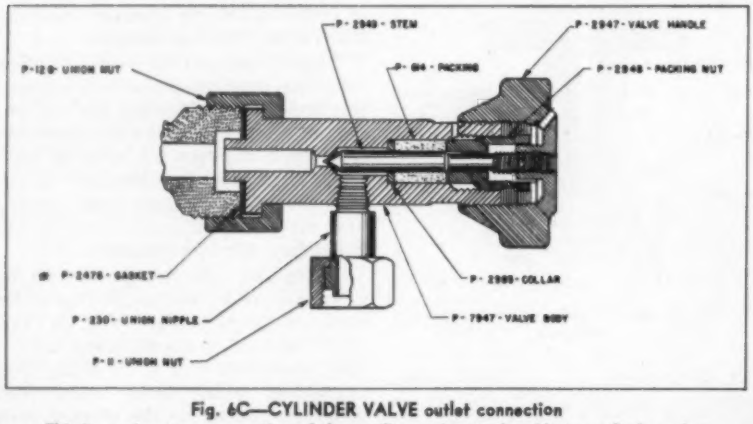

Fig. 6C—CYLINDER VALVE outlet connection
This is a union type connection of the auxiliary valve to the chlorine cylinder valve.

In making connections, gasket surfaces should be thoroughly inspected and cleaned, a new gasket of standard material should be used for each connection. Outlet threads on the valves of containers are NOT tapered pipe threads. Make certain that the threads on the appliances and unions are the same as those on the outlet valves, and never force connections that do not fit.

When a firm connection has been made, open the container valve slowly, being alert for a possible chlorine leak. Never use a wrench longer than 6 inches for operating a container valve. It is usually possible to eliminate a gas leak around the valve stem by tightening the packing nut.

If the practice of compounding (manifolding) ton containers is followed, to increase withdrawal rates, increased vigilance must be observed in connecting and disconnecting.

When is the Chlorine Cylinder or Ton Container Empty?

Three observations are commonly employed to indicate that chlorine cylinders or ton containers are becoming empty. Loss in weight is the most dependable indicator of the amount of chlorine remaining in a cylinder or ton container.

Loss in Weight

Producers and repackagers load precise weights of chlorine in the various packages, and tare weights are carefully checked. Therefore, scales used by consumers in conjunction with chlorine feeding should be in good operating condition. Close observation of weight loss should always be made, and this applies especially when approaching the point where a change to full packages must be made.

Pressure Drop

Two other indicators, while not as useful as loss in weight, do serve to warn that cylinders or ton containers are becoming empty. One is the observation that the gauge connected to the chlorine gas transmission line shows a pressure drop, and the other is evidence of a vacuum break (sucking air) caused by lowering of pressure in the chlorine supply system.

Both of these indicators provide warning in advance of depletion of cylinder or container contents. Note that the chlorine gas pressure gauge does not measure the volume or weight of chlorine remaining. Pressure exerted by confined chlorine gas depends on the temperature: theoretically, one pound of chlorine will,

Fig. 7—TESTING for a chlorine leak
A cloth or swab moistened with ammonia is held near each connection in the chlorine gas line.

MATHIESON QUALITY PRODUCTS FOR TREATMENT OF WATER AND WASTES

TREATMENT OF RAW WATER • CLARIFICATION OF TURBID AND COLORED SUPPLIES • REMOVAL OF TASTES AND ODORS • WATER SOFTENING • STERILIZING NEW EQUIPMENT • CLEANING SUPPLY EQUIPMENT AND INSTALLATIONS • EMERGENCY CHLORINATION

HTH GRANULAR

The following outstanding properties of HTH have gained wide acceptance for the product by water works operators and others using HTH in water treatment: Dependable strength of over 70% available chlorine, high stability that maintains the product at full strength even after months of storage at summer temperatures, low calcium chloride content that eliminates hygroscopic tendencies, rapid and complete solubility of the active element in water.

The available chlorine in HTH is in the form of true calcium hypochlorite, the formula of which is $Ca(OCl)_2$. When consideration is given to the light-weight, non-returnable containers in which HTH is shipped, its available chlorine per pound of gross weight exceeds that of liquid chlorine in the 100- and 150-lb. cylinders. Moreover, its use involves none of the hazards that attend the handling and use of liquid chlorine. It is little wonder, therefore, that water works men avail themselves of this convenient, safe source of available chlorine wherever practicable.

The 5-lb. cans of HTH Granular, packed 9 to the case, are particularly convenient for sanitization of newly laid pipelines, isolated water supplies and at locations where transportation of the chlorine carrier is a troublesome factor. For continuous or emergency hypochlorination of water supplies, the 100-lb. drum of HTH Granular may be a more economical unit. In determining the more desirable package, however, consideration should be given to the advantage of keeping a product not immediately needed in sealed 5-lb. cans rather than in a 100-lb. drum that is frequently opened.

HTH TABLETS

For convenient handling in many water treatment applications, HTH is also available as HTH Tablets. This product is simply HTH in the form of compressed, easy-to-handle tablets which dissolve slowly and provide a continuous source of available chlorine over an extended period of time.

HTH Tablets are made wholly of dependable HTH and contain 70% available chlorine the same as the time-tested granular product, HTH Granular. The tablets are stable and dust-free and have an unusually high degree of strength. HTH Tablets thus offer an exceptionally safe and convenient means of handling, measuring and storing available chlorine. HTH Tablets are packed in 100-lb. drums and in cases of six 7½-lb. cans.

HTH TABLET HYPOCHLORINATOR

By use of the HTH Tablet Hypochlorinator the convenience offered by the HTH in tablet form can be combined with accurate metering and feeding of hypochlorite solutions. This equipment, specifically designed by the Mathieson technical staff to dissolve HTH Tablets and to dispense the resultant hypochlorite solutions, provides a convenient and efficient method of feeding available chlorine at rates which can be accurately controlled and quickly varied to cover a wide range of operating demands.

The HTH Tablet Hypochlorinator is of practical design, compact construction, and attractive appearance; it is easy to install and very simple to operate. Moreover, HTH Tablet chlorination eliminates all measuring and weighing operations, and requires no preparation of stock solutions. The HTH Tablet Hypochlorinator is engineered to give long-time reliable service. Initial cost is low, and since the unit operates with no moving parts, maintenance and upkeep requirements are almost negligible.

HTH Tablets and the HTH Tablet Hypochlorinator can be applied successfully and economically in many cases where line or flow chlorination is desired. Such uses include chlorination of industrial wastes, industrial sewage, potable water, ponds, swimming pools and spray towers, and the feeding of hypochlorite solutions in dairies, canneries, bottling plants and other food and beverage plants.

SODIUM CHLORITE

Chlorine dioxide (ClO_2), is produced at the point of use by the interaction of chlorine and sodium chlorite ($NaClO_2$). The reaction takes place in a simple mixing chamber or solution generator, and the reagents may be (1) solutions of chlorine and sodium chlorite or (2) solutions of HTH, acid and sodium chlorite. The dilute chlorine dioxide solution thus formed is fed directly into the water for taste and odor control and for disinfection.

Mathieson Sodium Chlorite Technical is a dry, straw-colored, crystalline material containing 130 per cent available chlorine. It is non-hygroscopic, extremely soluble in water and very stable both in dry form and in solution. Packed in 100-lb. drums and 25-lb. pails.

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Activated Alum Brand

Activated Alum—the only alum designed exclusively for use in the field of water and sewage treatment—contains finely ground natural silicates, providing a free-flowing, less hygroscopic product of porous structure and higher alumina content. Activated Alum is used and preferred by several of the largest municipal water works in the U. S. A. Packed in 100-lb. six-ply paper bags.

PH-PLUS (Fused Alkali)

A special moisture-free alkali for water treatment, fused at 1,800° F. and cast in ½-lb. conical cakes. The cakes have a purity and rate of solution particularly desirable for pH control of swimming pool water and general industrial water treatment. Shipped in 100-lb. bags.

Other Mathieson Chemicals for Water Treatment:
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in 16 lb. . . . 105 lb. . . . 150 lb. cylinders and 1 ton containers.	70% available Chlorine . . . 3¼ and 5 lb. tins and 100 lb. drums	Gallons . . . Carboys and Tank Wagon Deliveries

No matter where your plant is located, Jones will deliver your chlorine with utmost efficiency, speed and dependability . . . and in the *right container* to meet your requirements.

But service is just part of the Jones story. Jones Chlorine products are processed by quality control methods to assure *uniform* top quality. Jones Chlorine has been specified for years by the U. S. Army and Navy as well as hundreds of cities and private concerns. If you have a problem in the field of water purification or chlorination of sewage and industrial wastes, let us help you. Write, phone or wire for information.

JOHN WILEY JONES CO.

Caledonia, N. Y., Beech Grove, Ind. (Indianapolis), Jacksonville, Fla., Charlotte, N. C., Torrance, Calif.

at a given temperature, exert as much pressure as will 2,000 pounds. It is emphasized that low readings of the chlorine pressure gauge merely indicate the probability of lowered tank contents.

Vacuum Loss

On chlorine feeders of the visible vacuum type, "bubbling" of air into the bell jar may indicate reduced pressure in the chlorine system. Depending on the feed rate, "bubbling" may proceed for varying lengths of time before a full cylinder or container must be placed in service. Chlorine feeders utilizing a rotometer, which measures gaseous chlorine flow, will perform in much the same manner, but rotometer readings will tend to drop off.

It will be noted that accuracy of chlorine dosage suffers when "bubbling" occurs or rotometer readings are unsteady. Changes to full chlorine cylinders or containers should be made promptly when this condition is coincident with loss of weight readings. It is obvious that economical usage precludes efforts to evacuate the last traces of gaseous chlorine from cylinders or containers.

Producers of liquid chlorine do completely evacuate chlorine from all returned packages. This is essential, because all cylinders, containers and tank cars are inspected internally prior to refilling. Another step includes removal, reconditioning and replacement of all chlorine valves.

Empty chlorine cylinders and ton containers should be removed from service immediately, tagged as empty and placed in a separate area to prevent possible confusion with full packages. Chlorine producers recommend prompt return of all empty packages as well as return of full packages considered to be in excess of adequate inventory.

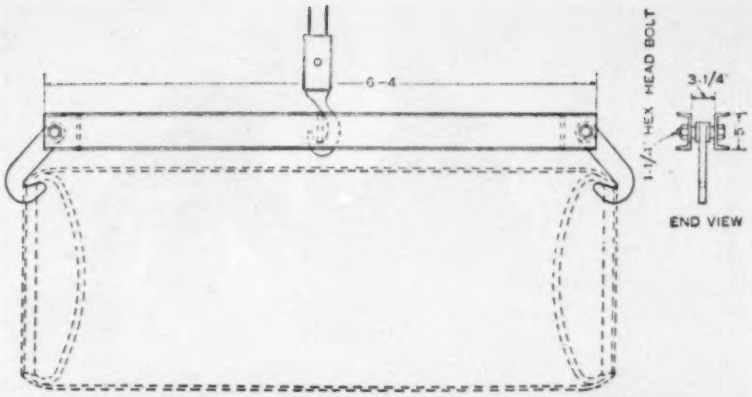


Fig. 8—LIFTING CLAMP designed for chlorine ton container handling

Fig. 9—STORAGE and handling facilities for chlorine ton containers
Lifting clamp is raised by overhead 3-ton hoist. Roller cradles facilitates positioning and connecting containers to discharge line.

Fig. 10—CONNECTED chlorine ton container
Gaseous chlorine is withdrawn from the upper valve. See Fig. 2 also.

Procedures involved in handling liquid chlorine differ from those in handling chlorine gas only insofar as vaporization is concerned. Liquid chlorine is withdrawn from the ton container through the lower outlet valve and is conducted to an evaporator of the type commercially available from equipment manufacturers. Vaporization of the chlorine is accomplished by heating within the evaporator. The gas is delivered to the metering equipment under constant temperature and pressure. Visual or orifice type flow meters may be employed, with or without recording equipment.

Handling Single Unit Tank Cars (16, 30 and 55 tons)

The necessity for caution in handling tank cars containing chlorine has long been recognized by the producers and by the Interstate Commerce Commission. Accordingly, those concerned with safe handling of the several tank car sizes must observe requirements which appear in sections of Agent H. A. Campbell's Freight Tariff No. 8*. Full legal requirements which must be met in unloading chlorine tank cars may be found in Sections No. 74.560 through No. 74.563 of Freight Tariff No. 8.

In addition to compliance with I.C.C. regulations the consumer, in order to assure maximum safety,

*Issued by H. A. Campbell, Agent, Bureau of Explosives, 30 Vesey Street, New York 7, N.Y.

Fig. 11—TANK CAR angle valve connected to deliver liquid chlorine
The angle valve (see Fig. 4) is located inside car dome; pipe wrench is to be no longer than 18 inches. Discharge line has flexible loop at car end.

should familiarize himself and his employees with the general recommendations of his chlorine supplier. Helpful suggestions are contained in technical service department chlorine bulletins, The Chlorine Manual** and published reports from operators experienced in tank car handling.

Typical of the legal requirements which must be met in order to unload chlorine from single unit tank cars is the necessity for a consumer to: acquire a private railroad siding; allow only reliable persons properly instructed and made responsible for compliance with regulations to perform unloading operations; place caution signs so as to warn of the operation in progress; detach unloading lines whenever unloading operations are suspended; have the car attended by a responsible person whenever the car is connected to an unloading device; be sure that complete unloading is followed by tightening all valves, removal of unloading connections and tightening of all other closures.

Producers have made general recommendations which amplify the legal requirements and provide further techniques in safe handling of tank car chlorine. Typical of these recommendations are: the derail protection of cars being unloaded; limit to 18 inches of the pipe screwed into a tank car discharge valve; use of a pipe wrench no longer than 18 inches in making tank car connections; provision of a flexible arrangement at the tank car end of the discharge line; use for chlorine service of extra heavy black iron or steel pipe with clean, sharp threads; painting of chlorine piping a distinctive color (yellow is most common) to guard against mistakes in identifying pipe lines; and provision of approved gas masks for emergency use.

The legal requirements and general recommendations cited are admittedly incomplete, the intention being to suggest that many precautions must be taken in handling single unit tank cars —and additional procedures are required to limit sources of potential hazard. Fig. 11 illustrates details of a connection being made to a single unit chlorine tank car at a sewage treatment plant.

Summary

Packages containing liquid chlorine must be treated with the respect which they deserve, in order to insure safety. It might be said that experience, not personal, but the type learned from others, is the best teacher of proper procedures to follow in handling chlorine.

**Copies are available from The Chlorine Institute, Inc., 50 East 41st St., New York 17, N.Y.

II—Chlorine Feeders

PART I of this series was devoted to discussing the characteristics and handling of packages in which commercial liquid chlorine is available. In this part, several types of chlorine gas feeders will be described, together with principles of their operation and maintenance.

Chlorine dispensing equipment is designed to control, measure and apply chlorine in the *gaseous* phase. Serious difficulties arise when attempting to secure accurate metering of *liquid* chlorine. The following statements apply generally, and reveal important reasons for designing equipment to handle gaseous chlorine:

1. Chlorine in the gas phase lends itself readily to constant pressure control.
2. Chlorine gas feed may be controlled either manually or automatically.
3. Gaseous chlorine may be metered with either visual or orifice type flow meters, with or without recording instruments.
4. Chlorine gas is readily diffused into a liquid medium at the point of application.

Operating Principles

Equipment for dispensing gaseous chlorine is designed to utilize the principles of pressure (direct) feed, or of vacuum feed. The dispensing apparatus is connected either to the outlet valve of a cylinder standing vertically (Fig. 12), to the upper outlet valve of a horizontal ton container, to the gas valve of a single unit tank car, to the outlet regulator of a vaporizer, or to a valve located in the chlorine gas piping system.

The accuracy of a chlorine gas metering system relies basically on constant temperature and pressure conditions. The piping system delivering chlorine gas to the measuring device must be free of loops or pockets and avoid areas of low temperature, such as windows and cold walls. It is desirable to protect chlorine gas lines against temperature changes by insulating the piping system where necessary. Many operators install pressure controlling devices adjusted to maintain pressure within the temperature range where chlorine will not reliquefy in the chlorine piping system.

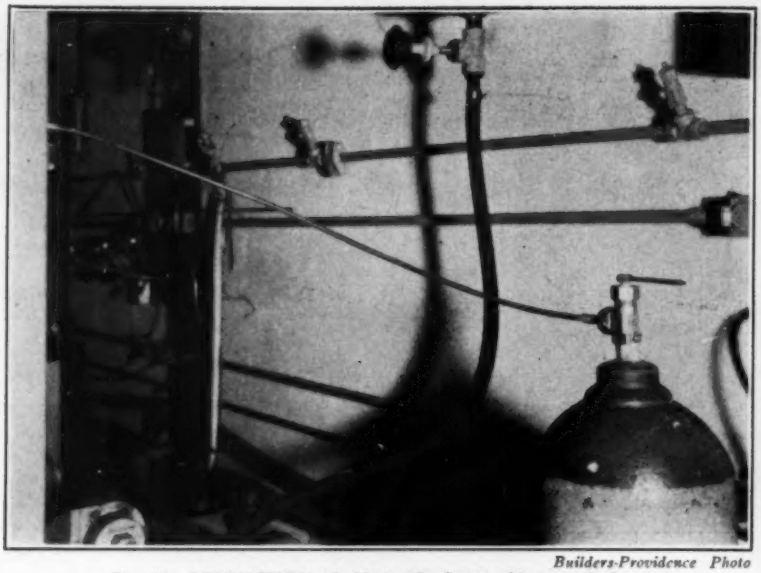
It is suggested that a check of injector operation be made each time a vacuum chlorinator is placed in service. It would appear obvious that if an injector will pull air through the vent lines, for example, it will remove chlorine gas.

All types of chlorine feeding devices are connected to the chlorine piping system in such a manner that chlorine flow may be valved off when the feeder is out of service (Fig. 13).

Vacuum Feed of Chlorine

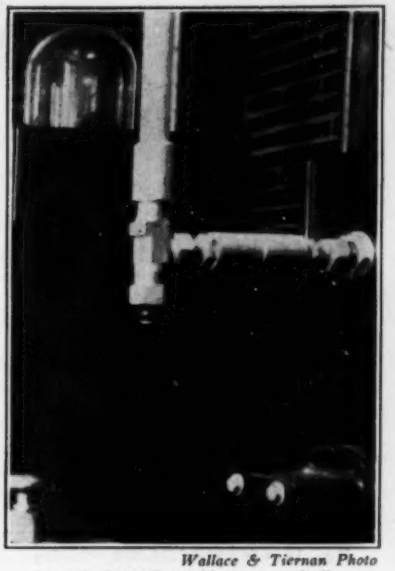
(Visible Vacuum Type)

Feeders of the visible vacuum type are characterized by a glass bell jar which encloses the chlorine pressure



Builders-Providence Photo

Fig. 12—CONNECTION of chlorine feeder to chlorine cylinder
Flexible tubing conveying gas should slope upward from the cylinder.



Wallace & Tiernan Photo

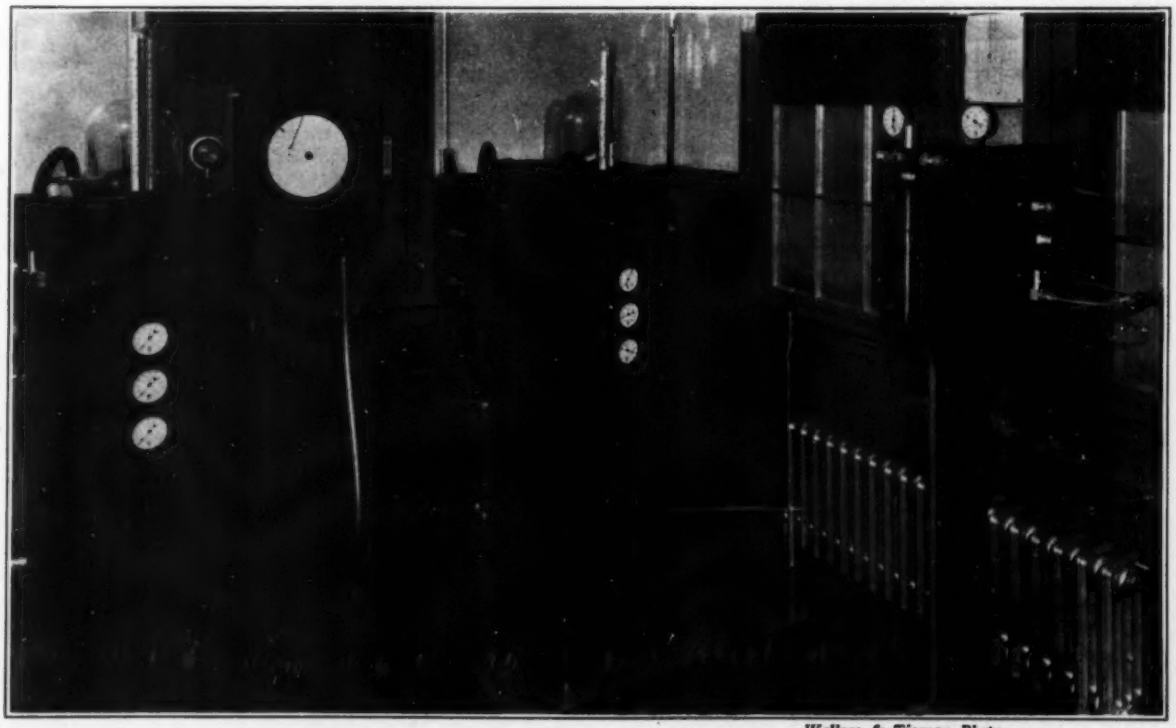
Fig. 13—VALVE in chlorine supply line
Union coupling connects line to feeder.

reducing valve, metering orifice, and vacuum relief float; it may or may not enclose a calibrated feed rate tube. Chlorine is confined within the bell jar by means of a water seal maintained by an auxiliary water line. Two chlorine feeders of the visible vacuum type are illustrated in Fig. 14.

Chlorinator

As the name implies, chlorine may be fed by a visible vacuum Chlorinator* only when a condition of partial vacuum exists within the bell jar, and when all valves in the chlorine piping system are open. Pressure less than atmospheric is maintained within the bell jar by means of a water operated injector. The injector also removes chlorine at a rate dependent upon the metering orifice size and the amount of negative pressure within the bell jar.

*Product of Wallace & Tiernan Co., Inc., Newark, N.J. The term is also applied to a product of the Chemical Equipment Co., Los Angeles, Calif.



Wallace & Tiernan Photo

Fig. 14—CHLORINATORS, two visible vacuum type chlorine feeders, and an ammonia feeder
Compact installation in the headworks of the Tacoma, Wash., Water Dept.

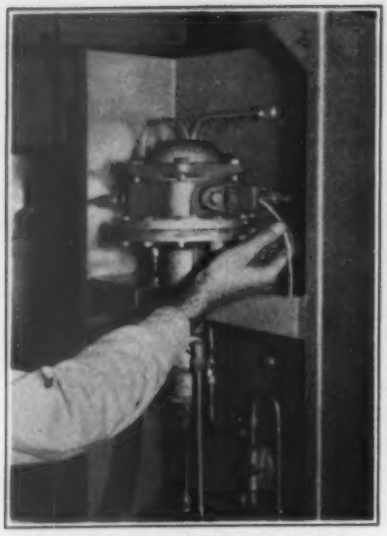


Fig. 15 — SPRING-LOADED chlorine valve
Gas metering orifice being cleaned.

Builders-Providence Photo

Fig. 16—CHLORINIZER rate setting by manual control
Gas flow is visible in calibrated rotameter type metering tube.

Chlorine gas is, therefore, mixed with water at the injector, and the mixture flows to the point of application through rubber hose or other materials resistant to chlorine water. The volume of water required to operate the apparatus may be minimized by correct sizing of injector throat and tail piece, as well as by proper feeder selection.

All those components of the visible vacuum chlorinator that are exposed to moist chlorine are constructed of corrosion resistant materials. Preventive maintenance is indicated, however, in the interests of long and economical service. As one would expect, chlorine within the bell jar takes on moisture from tray water used as a seal, hence good practice would involve removal of chlorine from the bell jar when taking a feeder out of service for any reason. This is accomplished by closing the valve on the chlorine supply line allowing the injector to continue in operation. Reduction of the gas pressure on the water seal surface will permit air to be drawn in through the vacuum relief line. Sufficient time should be allowed for complete chlorine removal from the bell jar, since minute amounts of moist chlorine exert great corrosive action.

In maintenance of the equipment, special attention should be given to the chlorine pressure reducing valve. Free movement of the ball float can be assured by preventing excess scale formation on the valve and seat. Extreme care must be exercised in cleaning this valve, so that the valve stem and seat are not damaged. Bell jar surfaces should be kept clean to permit visual examination of the several important items discussed above. Screens provided in the inlet piping should be cleaned regularly. The advantage of duplicate installations may be readily seen when continuous chlorination is mandatory, since one machine may be removed from service for either routine or emergency maintenance service.

The visible vacuum chlorine feeder may be easily adjusted for feed rate, but the simplicity of the operation may be improved by a preventive maintenance schedule. Changes in feed rate are accomplished by raising or lowering a column of water which alters the rate of chlorine removal from the bell jar through the metering orifice tube. The device used to determine the height of the water column is referred to as the "adjustable riser." A silver tube, it is free to move through a packing gland, which must fit closely to prevent water or air leakage. The riser will move freely if the tube is kept polished and if gears and pivots in the adjustment mechanism are properly lubricated.

Experience will indicate what spare parts are essential to insure continuous availability of installed equipment. It is suggested the following items be stocked as basic to a spare parts inventory: vacuum relief float, bell jar, chlorine pressure reducing valve and float, orifice tube, metering tube, adjustable riser, injector throat, injector tail piece, packing and assorted gaskets.

Vacuum Feed of Chlorine

Visible Flow

Chlorine feeders of the visible flow type are characterized by the visible flow of dry chlorine gas through a rotameter, and by mixing the gas with water at an injector. The apparatus is connected to the chlorine piping system in such a manner that chlorine flow may be valved off when the feeder is out of service. Chlorine may be fed only when conditions of partial vacuum exist within the equipment and when all valves in the chlorine piping system are open.

There are several dispensers of this type presently available to the sanitation field. The basic principles of their operation will be discussed.

Chlorinizer

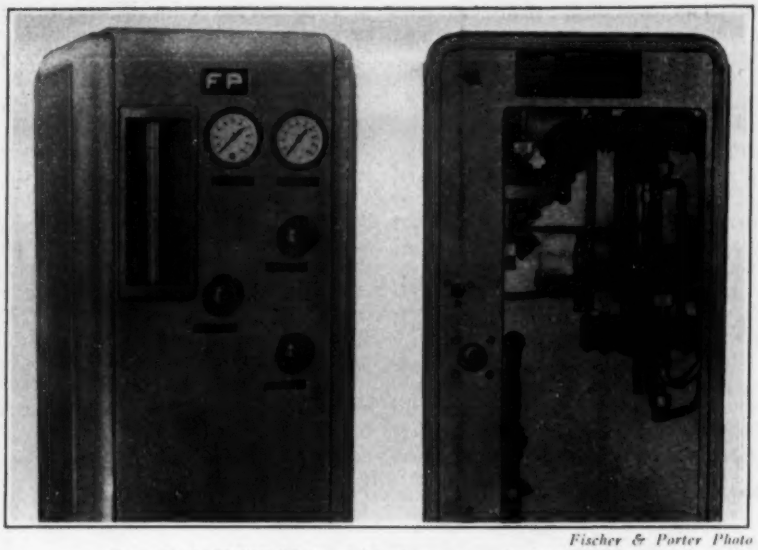
The Chlorinizer* utilizes the vacuum induced by an injector to maintain a continuous flow of dry chlorine gas through a fixed metering orifice, rotameter, and bell jar. The chlorine gas is subsequently mixed with injector water for delivery to the point of application. Dosage control is accomplished by adjustment of a rate control valve which alters the pressure induced on the spring-loaded chlorine control valve (Fig. 15).

The control valve is in two sections, separated by a flexible tantalum diaphragm. The upper section, which reduces the chlorine gas pressure from relatively high to a partial vacuum, contains a needle valve upon which dosage control depends. The lower section, which contains water under

*Product of Builders-Providence, Inc., Providence, R.I.

Builders-Providence Photo

Fig. 17—CLEANING the metering tube
This is good preventive maintenance.



Fischer & Porter Photo

Fig. 18—RATOCHLOR for visible flow vacuum feed of chlorine
Rate control valve alters flow rate from the rotameter.

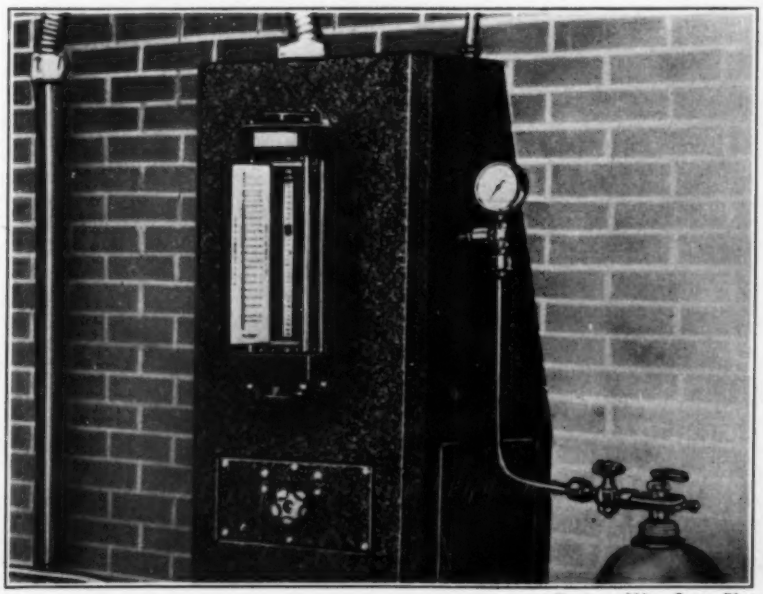
pressure, provides the means by which the needle valve is adjusted. Any alteration of pressure in the lower section is transmitted by means of the flexible tantalum diaphragm to the needle valve in the upper section. The rate valve is controlled as illustrated in Fig. 16.

A calibrated rotameter type metering tube and float provide a visual means of flow observation. The metered chlorine gas remains dry until it passes into a bell jar, still under vacuum conditions, for delivery to the injector.

The bell jar mentioned above serves several useful functions: it encloses the metered gas, contains the chlorine gas draw-off pipe and a float-operated vacuum release which limits the amount of vacuum induced. The bell jar is suspended on a rod from the lower section of the chlorine control valve mentioned above, in such a manner that any interruption in vacuum conditions causes the needle valve in the upper section to react accordingly. Thus, the flow of chlorine to the metering component is stopped in the event of vacuum loss. A vent to outside atmosphere is also provided to remove chlorine vapor from the bell jar.

Routine preventive maintenance includes inspection of all threaded connections, tightening of all valve packing collars and keeping the metering tube and float clear at all times (Fig. 17).

Experience will indicate what spare parts are essential. It is suggested that following items be stocked as basic to a spare parts inventory: set of glass parts, spare rotameter tube and float, packing material, diaphragms and assorted gaskets.



Everson Mfg. Corp. Photo

Fig. 19—STERELATOR chlorine feeder, visible flow vacuum type
A rotameter is the gas measuring device employed.

Ratochlor

The Ratochlor* utilizes the vacuum induced by an ejector to maintain a continuous flow of dry chlorine gas through a rotameter type measuring tube (Fig. 18). The metered gas is drawn into the ejector supply water for delivery as a water solution to the point of application. Dosage control is accomplished by the adjustment of a rate control valve which alters the flow rate from the rotameter.

Chlorine gas enters the dispenser from the chlorine supply system at pressures depending on the surrounding temperature. Pressure reduction and vacuum regulation are accomplished in a spring loaded regulator, the vacuum and atmospheric sides of which are separated by a flexible plastic diaphragm. Since the conditions of vacuum are closely regulated, chlorine gas is measured, then passes through the adjustable rate valve for delivery to a second regulator which

*Product of Fischer & Porter Co., Hatboro, Pa.

has as its function the maintenance of a constant flow rate for any manual setting of the rate valve.

An atmospheric venting system is built into the apparatus to remove chlorine vapor from the internal system to outside atmosphere. Diaphragm failure in the spring loaded vacuum regulating device mentioned above will immediately shut off the gas flow. A pressure relief valve is included in the ejector assembly.

In the interests of metering accuracy, a clean metering tube and float are of basic importance.

Items basic to a spare parts inventory will be learned from experience; however, a spare rotameter tube and float, diaphragms and assorted gaskets should be on hand at all times.

Sterelator

In the Sterelator*, chlorine gas enters the upper valve chamber of the chlorine gas regulator and shut-off valve where pressure is reduced from that existing in the chlorine piping system (Fig. 19). The gas then flows under semi-vacuum conditions into the metering system through a throttling valve.

The metering component is a tapered tube rotameter type measuring device, calibrated to read directly in pounds per unit of time. Following the rotameter, the metered gas flows to a vacuum tower for delivery to the suction side of the vacuum-producing injector. The gas is removed from the upper end of the vacuum tower through a suction draft tube, which also removes sufficient water to satisfy the remaining demand of injector suction. The lower portion of the vacuum tower is immersed in a float controlled, constant level reservoir, which serves as a water seal between the metered gas and the atmosphere.

Safety features of the apparatus include a positive, spring actuated shut-off at the chlorine gas regulator and an hydraulically operated vacuum breaker which provides a vent to the outside atmosphere. The vacuum breaker is connected to upper as well as the lower end of the vacuum tower.

*Product of Everson Manufacturing Corp., Chicago, Ill.

Pressure Feed of Chlorine

Direct Feed

Direct feed equipment provides for metering dry chlorine gas and is installed in the piping system between the chlorine package and the point of application. The gas is not injected into a minor stream of water for eventual blending at the point of application; rather, the chlorine is conducted under necessary pressure conditions to the major flow of liquid being chlorinated.

The apparatus includes gauges for determining pressures in the chlorine piping system and within the device. Metering components of pressure feed devices may be either the rotameter or pressure differential (manometer) types, with provision for pressure compensation to insure measuring accuracy. Anti-flood protection should be provided to function automatically during shutdown periods or when excessive back pressure exists at the application point.

Maintenance of direct feed apparatus consists of regular inspection of the chlorine piping system, shut-off valve, gauges, control valve and all connections. The metering device should be kept clean at all times.

Cleaning Procedures

It should be noted that the removal of chlorine residue from hard rubber floats and other portions of the feeding equipment is included in good housekeeping practices. While no perfect solution to the cleaning problem has been reported, the use of certain solvents—methanol (wood alcohol) and carbon tetrachloride—is suggested in addition to water and the time-tested scraping technique.

Caution must be exercised when employing the organic solvents, since a temperature rise (particularly when using methanol) may occur during the operation. The following procedure is recommended when cleaning chlorine feeder parts: Wash with water to remove water soluble material; wash next with a recommended solvent, using care to avoid breathing

M.S.A. Photo

Fig. 20—GOOD VISIBILITY is an important feature of modern gas masks.
Men are wearing self-contained breathing apparatus of a type in which the user's breath generates oxygen from a chemical compound.

M.S.A. Photo

Fig. 21—CHEMOX apparatus, an oxygen generating device
Maximum canister service is 45 minutes.

Scott Aviation Corp. Photo

Fig. 22—SCOTT AIR-PAK self-contained compressed air device
Maximum service of refillable cylinder is 30 minutes.

any fumes released; thoroughly rinse free of solvent and dry completely before replacing the parts for service.

It is pointed out that use of methanol and carbon tetrachloride as cleaning solvents avoids the possibility of forming undesirable chloro compounds if insufficient rinsing is accomplished since methanol oxidizes to carbon-dioxide and water and carbon tetrachloride is the product of chlorinated methane; however, good practice indicates thorough water rinsing followed by air drying.

Common practice has been to scrape the dry residue from the outer surfaces of hard rubber components of feeding machines. Sharp instruments, such as knives or razor blades, together with abrasives, sand paper and steel wool must be used carefully to avoid possible injury to the equipment. When the scraping procedure is followed, caution should be observed to avoid inhaling the dusty residue.

Chlorine Hydrate

The formation of chlorine hydrate in some chlorine feeders, commonly referred to as "chlorine ice," results from high concentrations of chlorine subjected at reduced pressure to temperatures below 49.2° F. Faulty feeder operation or poor chlorine quality are not the cause of this condition, which may interfere with metering accuracy or adequate vacuum relief. The solution to this problem is to raise the temperature of the affected area or warm the influent chlorine gas. By far the safest method is to warm the affected area by adding warm make-up water. It is possible to warm the influent gas, but extreme caution must be exercised; guidance in this operation should be obtained from the chlorine supplier or equipment manufacturer.

Automatic Control

Chlorinating equipment has been developed which enables automatic control of chlorine dosage. Accessories are available which will vary the feed automatically proportional to the flow of the liquid being chlorinated, or will effect intermittent chlorine dosage where desired.

General Suggestions

Close attention should be paid to all portions of the chlorine piping system and feeding equipment for evidence of gas leakage. Inspection should be made of all threaded connections and valves, and should include prompt corrective action for leaks. Packing glands tend to dry out and should be replaced at regular intervals.

Leakage in water piping and valves should also be eliminated, if for no other reason than conservation. External condensation on water lines can be the cause of expensive pipe replacement and would indicate the need for protective paint application.

Vents to the out-of-doors are frequently overlooked in routine maintenance schedules. It should be noted that vents to the atmosphere constitute important safety devices. The possibility of water entering vent lines, thus serving as a trap, must be eliminated. Freezing or plugging with foreign material must be avoided.

III—Chlorine Gas Masks

A SERIES of articles dealing with techniques for handling a toxic gas such as chlorine should include information regarding respiratory protective devices. This installment will describe functions of the U.S.

M.S.A. Photo

Fig. 23—M.S.A. self-contained demand type oxygen device
Maximum service of refillable cylinder is 30 minutes.

M.S.A. Photo

Fig. 24—M.S.A. canister type chlorine service mask in use
Gas concentration determines service of canister.

Bureau of Mines, general types of chlorine gas protective devices, their specific uses, and the limitations of each type.

Bureau of Mines

The Bureau of Mines of the United States Department of the Interior performs valuable services in connection with the promotion and use of safe, satisfactory and reliable respiratory-protective devices. To accomplish this broad program, the Bureau has established schedules of minimum requirements for the several types of breathing apparatus. Approval tests on self-contained breathing apparatus are conducted by the Safety Branch of the Bureau; tests on all other respiratory-protective devices are carried out by the Health Branch.

Equipment which has been submitted for approval and meets the Bureau's requirements is granted a certificate of approval, stating that the apparatus has passed the Schedule of Requirements and describing existing limitations. It should be noted that if approved devices purchased on the open market fail to pass prescribed tests, the approval certificate for the device may be rescinded.

Lists of approved devices are published periodically for the information of the public. A recent list was published as Bureau of Mines Information Circular 7636 dated June, 1952.

Types of Chlorine Gas Protective Devices

Devices classified as respiratory protective include self-contained breathing apparatus, gas masks and supplied-air respirators.

All devices satisfactory for chlorine protection consist of a face mask connected either to an oxygen or air supply, or to a suitable canister which generates oxygen, or to a canister capable of absorbing specific quantities of chlorine from the atmosphere.

The face mask is molded of flexible material and, when worn, is held in place by means of straps and friction clasps (see Fig. 20). *The mask must fit tightly:* allowing leakage of gas through or around the face mask is obviously courting disaster. Immediate rejection or repair is the only procedure when the face mask leaks.

Transparent ports in the face mask make vision possible. These ports vary widely in size and shape, and modern masks include circulation for fog prevention during use. Protective devices for use in a chlorine atmosphere should be restricted to those which include eye protection, due to the irritating nature of moist chlorine.

Provision for exhaust air is accomplished by various types of valving devices which remain tightly closed during the intake cycle of breathing.

Connections between the face mask and other parts of the apparatus utilize flexible tubes which permit free head movement. This tubing is resistant to crumpling and deterioration, and is vital to continued dependability of the mask; hence it should be subject to frequent critical inspection and testing for leaks.

Mask Inspection

Face masks and connecting tubing must be inspected regularly, certainly at intervals no longer than quarterly. The inspection should include visually examining all parts of the apparatus, then placing the mask upon the face, as in actual service.

To test for leaks, pinch off the corrugated connecting tube near the face-piece and inhale deeply. The face-piece must collapse completely to indicate airtightness of mask and tube connection. A similar procedure may be followed to check the condition of the connecting tube, by pinching the tube near the connection farthest from the face-piece and inhaling deeply.

In the event that leaks are found in either the face-piece, tube or tube connections, and if tightening of elastic straps and bolts does not prevent leakage, the only solution is to replace the complete face-piece with flexible

tube attached. It is dangerous to take chances with a leaky gas mask, since a user will enter a contaminated atmosphere believing that he is protected against chlorine gas, only to inhale gas through the leaky parts of the device, with possible dire consequences.

Self-Contained Breathing Apparatus

As the name implies, a self-contained breathing apparatus is equipped with an oxygen or air supply as an integral part of the protective device. Use of this type of equipment is mandatory in working areas which are deficient in oxygen, or when a toxic gas exists in a concentration so high (above 2 per cent) that canister type masks are rendered useless.

The Bureau of Mines has issued certificates of approval for the following self-contained respiratory-protective devices (as of June 1, 1952):

Chemox oxygen breathing apparatus (¾-hour self-contained oxygen breathing apparatus). Approval BM-1307, issued to Mine Safety Appliances Co. October 3, 1946. Cat. No. B-46328 Chemox Canister, Cat. No. B-45151.

Scott Air-Pak self-contained breathing apparatus (½-hour self-contained compressed air breathing apparatus). Approval BM-1308, issued to Scott Aviation Corp., October 3, 1946. Model 6000-A2M.

M.S.A. demand-type oxygen apparatus (½-hour self-contained compressed oxygen breathing apparatus). Approval BM-1309, issued to Mine Safety Appliances Co., October 3, 1946. Cat. No. B-45950. Oxygen cylinder, Cat. No. B-45153.

M.S.A. demand-type air apparatus (½-hour self-contained compressed-air breathing apparatus). Approval BM-1310, issued to Mine Safety Appliances Co., November 26, 1946. Cat. No. B-46307. Air Cylinder, Cat. No. B-45843.

As will be noted from the above list, self-contained breathing apparatus operates for a specified length of time in an atmosphere deficient in oxygen, an important factor when high toxic gas concentrations exist. The time element is most important and the devices approved by the Bureau of Mines indicate service time remaining.

In the case of Chemox apparatus, a 45 minute timer may be set, with discard of a canister after use of any amount. The device may be tested for leaks by grasping the flexible inhalation tube and inhaling deeply. Collapse of the face piece indicates sufficient tightness and proper functioning of the exhalation valve. Similar procedures are used to insure tightness of the inhalation valve and exhalation tube. The breathing bag may be checked by depressing both elbows firmly, if the bag does not deflate, the apparatus is tight.

The Chemox apparatus is an oxygen generating, canister-type device which utilizes the user's breath to activate an oxygen generating compound. This device is light weight (13½ lbs., complete) and has no high pressure cylinders, valves or fittings (see Fig. 21).

The Scott Air-Pak apparatus utilizes compressed air which is supplied to the user from a back-carried refillable cylinder, having 40 cu. ft. capacity, sufficient for 30 minutes use at extreme exertion. This device features a demand regulator which gives continuous indication of air supply remaining in the cylinder. The regulator is equipped with a radium dial and is located in full view of the wearer. Protection against regulator failure is afforded by an emergency by-pass valve which will allow a constant flow of air to the mask (see Fig. 22).

The M.S.A. demand-type devices each supply 30 minutes service, one utilizing compressed oxygen and the other compressed air. Both employ back-carried, refillable cylinders having 40 cu. ft. capacity, sufficient for 30 minutes use at extreme exertion (see Fig. 23).

The demand regulator continuously indicates the amount of service remaining and is located in full view of the wearer. The regulator may be by-passed in event of failure, providing a constant supply of air or oxygen to the face mask, with any excess air discharging through the exhalation valve or around the face mask.

Gas Masks Canister Type

Canister type respiratory protective masks are used extensively in the sanitation field, with an admirable history of service. They are satisfactory for chlorine service when a gas concentration of two per cent (20,000 ppm) or less prevails in the atmosphere (see Fig. 24).

It should be emphasized that canister type gas masks can be used safely only when oxygen is present in life-supporting concentration. Canisters remove contaminants during inhalation—they do not supply oxygen: the decontaminated volume of air supplied to the respiratory system must contain sufficient oxygen or suffocation will result. The rupture of a chlorine package coincident with fire where an oxygen deficiency could occur, could create a situation requiring the use of either self-contained or supplied air respiratory-protective devices to combat the emergency effectively.

The life of the canister depends on the concentration of chlorine in the atmosphere. Effective service life may be several hours when exposed to very low concentrations of chlorine, but at high concentrations a canister may have a service life of only 15 minutes. At Detroit, for example, the *average* life of the canister is set at two hours.

Another limitation applies to canister type gas masks besides that of gas concentration. A common oversight among operating personnel is found in canister inventory, where seals have been removed to render masks instantly available for protection. Canisters, installed in the mask proper *with seals broken*, do not retain their chlorine absorptive capacity for an extended period and must be replaced immediately after use, or within one year, even though not used. Spare canister inventory should be stored with seals intact and dated so that rotation of new supplies is possible. Canisters older than four years are unreliable and must be rejected.

The Bureau of Mines has issued certificates of approval for canister type gas masks suitable for use in a chlorine contaminated atmosphere. Such approval is included under schedule 14, a schedule which is changed from time to time so that Bureau requirements keep pace with technical advancements. Following are names and addresses of companies to which approvals have been granted (as of June 1952) as published in Bureau of Mines Information Circular 7636:

Acme Protection Equipment Co.
3037 West Lake St.
Chicago 12, Ill.

E. D. Bullard Co.
275 So. Eighth St.
San Francisco, Calif.

Davis Emergency Equipment Co.
45 Halleck St.
Newark 4, N. J.

Mine Safety Appliances Co.
Braddock, Thomas and Meade Sts.
Pittsburgh 8, Pa.

Willson Products, Inc.
Reading, Pa.

It is recommended that canister type masks be inspected *monthly* by checking the face mask and connecting tubing as mentioned earlier in this

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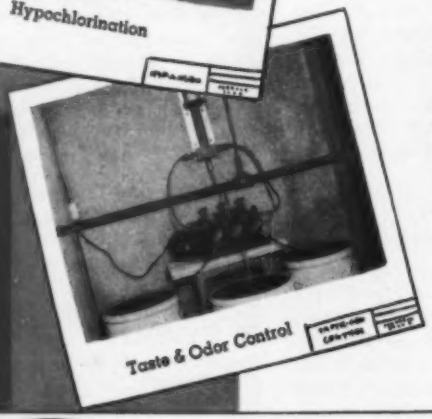


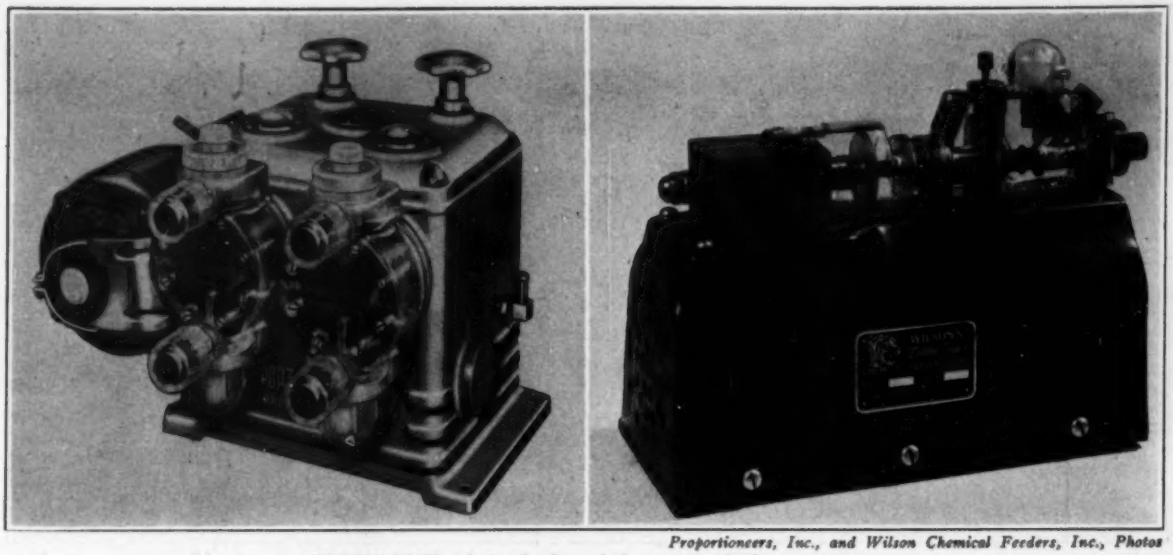
Proportioneers equipment packages save money in water and sewage treatment. They reduce operating costs and manpower expenses. They utilize economical chemicals. They save on maintenance and service charges. May we quote on your chemical feeding and water filtration requirements? Send for data and recommendations to Proportioneers, Inc., 376 Harris Ave., Providence 1, R. I.

PROPORTIONEERS

DIVISION OF B-I-F INDUSTRIES, INC.

BUILDERS IRON FOUNDRY • OMEGA MACHINE CO. • BUILDERS-PROVIDENCE, INC.

BIF METERS FEEDERS CONTROLS



Proportioneers, Inc., and Wilson Chemical Feeders, Inc., Photos

HYPOCHLORITE solution feeders of the positive displacement type

Fig. 25 (left) is a diaphragm type feeder which may be used to dispense two separate solutions or, by manifolding the discharge ports, one solution at double capacity. Fig. 26 (right) is a plunger type feeder.

article. Operating personnel must be thoroughly acquainted with all mask locations, spare canister storage, and mask inspection procedures.

Masks should be located immediately available to, but outside of, chlorine feeder and scale rooms, and the chlorine package storage area. Canister inventory should be so located that spares are easily accessible in a cool, dry place.

Supplied-Air Respirators Hose Type Mask

Hose type masks supply air to the wearer through a length of hose and are available with or without hand operated blowers. It is apparent that such a respiratory protective device must provide clean breathable air, delivered from outside the contaminated area to the wearer, thus caution must be exercised when using this type equipment, which usually is available with 150 feet of hose (75 feet without blower).

The air hose is of large inside diameter, approximately 1", to enable a wearer to secure air through it in case of blower failure. Resistance to deterioration and crushing weights are factors considered in designing hose for supplied air respirators.

It is again pointed out that hose type masks require provision of clean breathable air to the wearer, limiting their use somewhat in chlorine contaminated atmosphere. They may be used to good advantage, however, in tank cleaning, underground repair work and in other confined spaces.

The Bureau of Mines approves hose masks with blowers for respiratory protection in any atmosphere regardless of degree of contamination or oxygen deficiency, providing clean breathable air can be reached within the permissible hose length. The Bureau of Mines covers this class of equipment in Approval Schedule No. 19.

Summary

Increasing attention to safety programs in the sanitation field provides opportunities to analyze hazards existing in our plants. A critical survey of the entire chlorine handling system is certainly in order at any time. While leaks in piping and other appurtenances cannot be predicted, it is possible to predict at all times the condition of protective devices and safety equipment.

Every employee should be trained in the use of protective devices he is expected to use under emergency conditions. Regular rehearsals, for example, which include the entire testing procedure and wearing of the equipment will increase the efficiency of an operator faced with a combination of circumstances requiring immediate action—*and may save his life.*

IV—Hypochlorites

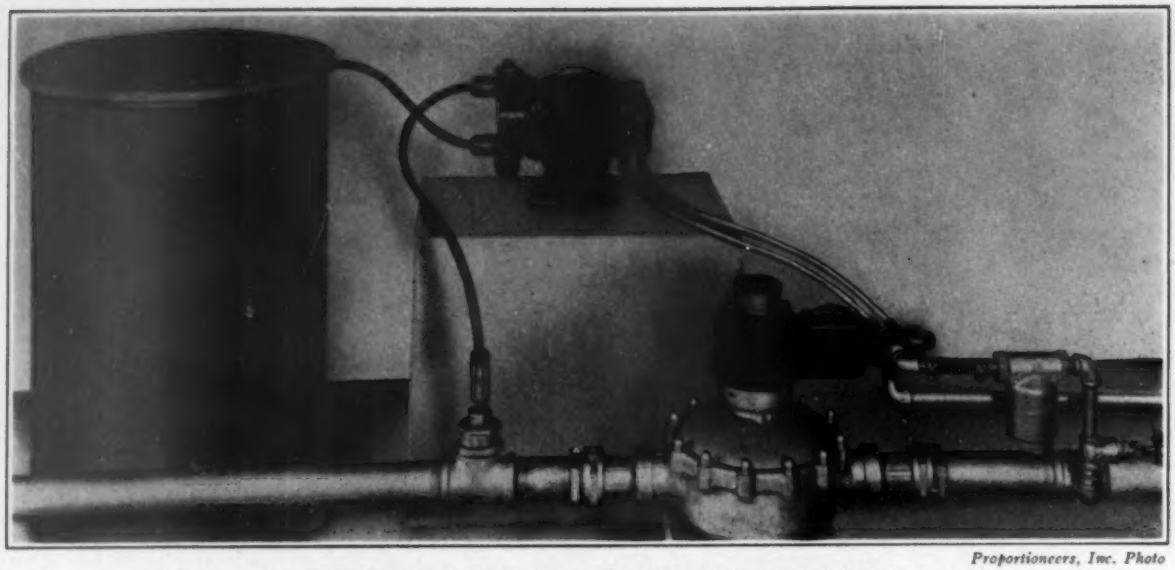
CALCIUM and sodium hypochlorites, often referred to as bleaches, have long been established in the sanitary field as sources of chlorine. The true calcium hypochlorite is particularly useful in this field, due to its concentrated form and ease of handling. It has not been possible to produce sodium hypochlorite as a stable powder, thus its use in the treatment of water and waste is somewhat limited. The uses and handling of these hypochlorites, together with the equipment commonly used in applying them, will be reviewed in this discussion.

Calcium Hypochlorite

Manufacturing techniques have advanced to the point where a relatively stable calcium hypochlorite containing 70 per cent available chlorine is produced. It is important to plant operators that the available chlorine content of successive shipments can be depended upon, with no major changes being required in pump settings or for preparing stock solutions.

Granular in texture, today's calcium hypochlorite is a dry white powder having a minimum of dusty fines. Reduction in caking tendencies has been accomplished by holding the calcium chloride concentration to a minimum. Stored in a dry atmosphere and kept in covered containers, lumping may be avoided.

Five pound, re-sealable cans and one-hundred pound drums are the package units generally found convenient by sanitation users. It should be noted that the one-hundred pound



Proportioneers, Inc. Photo

Fig. 27—INSTALLATION of automatic and proportional hydraulically operated hypochlorite feeder
Water flow through the meter maintains a set dosage rate in proportion to rate of flow.

drum is suitable for larger continuous users, while the five pound can should be specified where all of the contents will not be used immediately after opening.

Calcium hypochlorite, generally termed "high test" hypochlorite, may be utilized to serve any and all of the functions of gaseous chlorine, including disinfection, odor control, BOD reduction, control of sludge bulking, main sterilization, industrial waste oxidation and swimming pool sanitation. It is a product capable of providing readily available chlorine for emergency situations, even in large water and waste treatment plants.

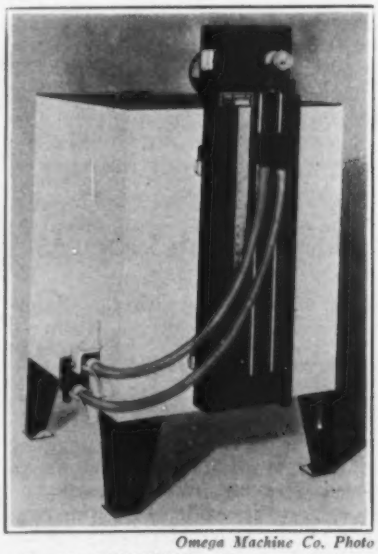
Handling Calcium Hypochlorite

Calcium hypochlorite is termed "relatively stable" because it is a highly active compound. Its activity creates a serious problem for the manufacturer: to produce a compound with maximum reactivity, yet one which will remain stable throughout production, packing, distribution and storage. It could be assumed that product deterioration will begin as soon as the packing operation is completed, yet the facts are that storage at 86° F for one year will reduce the available chlorine only 10 percent of that originally present. Cooler storage temperatures decrease even this small loss[1].

There is a problem involved in selecting the proper storage place for this useful and powerful chemical. Certainly, in the interests of preserving purchased available chlorine, low storage temperatures are indicated. While relatively stable under normal atmospheric conditions, reaction may occur spontaneously between hypochlorite and such organic substances as turpentine, ether, oils, sugar, fats and other oxidizable materials. For this reason implements, such as scoops, should be clean and dry when handling calcium hypochlorite. It also follows that the storage location should be well away from all combustible material. Rubber gloves and protective aprons should be worn when preparing and handling solutions of hypochlorite for any purpose.

Feeding Calcium Hypochlorite

Feeders for applying hypochlorite solutions require less investment than gaseous chlorine dispensers, a condition favoring their use in smaller treatment works. No attempt will be made here to specify at what flow rates one material should be selected over another, since variables such as chlorine demand and local requirements considerably alter installation selections.



Omega Machine Co. Photo

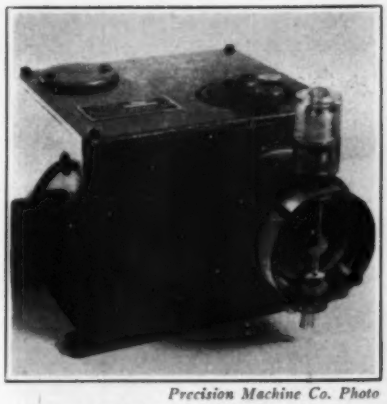
Fig. 28—LOWERING orifice type feeder
Electric drive operation of unit mounted on rubber lined tank.

Calcium hypochlorite is readily soluble in water. It is possible, therefore, to prepare solutions of varying concentrations, depending on the dosage required and the desired frequency of preparation. As is true with all chlorine solutions, materials resistant to corrosive attack should be used. Wooden, ceramic, or suitably coated steel dissolving tanks, and specially constructed feeding devices, will contribute to a satisfactory installation requiring a minimum of maintenance. As the granular product is free flowing, it may temporarily be dispensed through suitable resistant dry feeding equipment.

Numerous types of feeding devices are available which may be adjusted manually for dosage control; or dosage may be automatically regulated proportional to the flow treated.

Feeding "Chlorinated Lime" and "Soda Bleach"

Commercial chloride of lime or, properly speaking, "chlorinated lime," is a dry white powder containing about 35 per cent available chlorine when fresh. When exposed to air, this material rapidly absorbs moisture, becomes gummy, and its chlorine content is reduced. As a result, standard



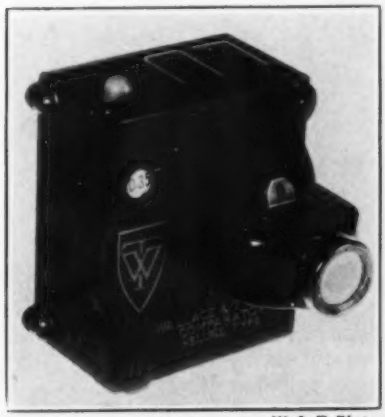
Precision Machine Co. Photo

Fig. 29—HYPOCHLORITE feeder

strength solutions of chlorinated lime can be prepared only by making an analysis of each batch for available chlorine. Obviously, chlorinated lime cannot be dispensed by dry feed devices.

Sodium hypochlorite or "soda bleach" solutions commercially available usually contain about 15 per cent available chlorine. The excess alkali present makes these solutions relatively stable: fresh solutions stored in a cool, dark location should be stable for at least three months. The stock solution may be applied as such, or may be diluted, to feed a relatively fixed concentration of available chlorine.

For sanitation uses the stability and convenience of true calcium hypochlorite (the "high test" hypochlorite) makes it superior to chlorinated lime and soda bleach. Except for emergency use, or for some special local condition, chlorinated lime and soda bleach are now considered impractical or too costly as sources of water and waste treatment chlorine.



W & T Photo

Fig. 31—CHLORINE residual comparator; disc type, orthotolidine is the indicator. Standards are permanent glass. Matching eyepiece is shown.

Solution Feed of Hypochlorites

Two general types of equipment for feeding hypochlorite solutions are available to the sanitary field: (1) Constant rate feeders, which require manual adjustment of rate, and (2) Proportional rate feeders, which automatically vary the delivery rate with changes in the flow being treated. Proper feeder selection depends on conditions existing at the point of application, including space requirements, water pressure conditions and supervision available[2].

Constant Rate Feeders

Delivery of hypochlorite solution at a fixed rate requires the attention of an operator to vary the dosage rate as a result of changes in water quality or flow rate at the point of application. The possibility of over or under chlorination exists, when feeding at a fixed rate, as a result of human error or insufficient sampling.

Feeders available for dosage at a constant rate usually are positive displacement, lowering orifice, or constant head orifice devices. Positive displacement units are either diaphragm (Fig. 25) or plunger (Fig. 26) type pumps, their pumping rate being a function of stroke frequency or stroke length.

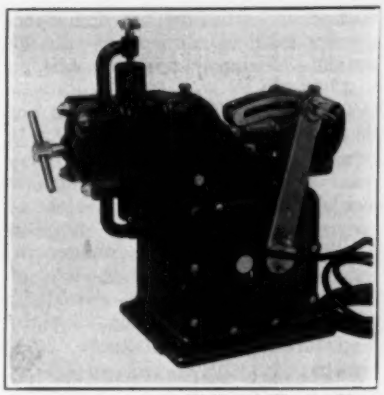
Lowering orifice type devices are based on the constant level principle, with an open end hose or pipe connected at or near the bottom of the tank (Fig. 28). As the open end is lowered, the solution flows to the point of application through the connection mentioned above.

Constant head orifice devices utilize the well-known constant level float valve which provides a constant head above a calibrated orifice.

Proportional Rate Feeders

The possibility of inaccurate chlorine dosage referred to earlier is materially reduced when the feeding equipment functions proportional to flow. It is possible to adapt all the above devices to proportional flow, with the exception of constant head orifice boxes.

Where disinfection is the primary purpose of hypochlorination, uninterrupted service is mandatory. Reliance usually is placed on the installation of duplicate equipment which would be available in event of mechanical failure of the apparatus in service. Interruptions due to electrical failure would indicate that hypochlorite dispensers in continuous service should be powered either hydraulically or mechanically.



Wallace & Tiernan Photo

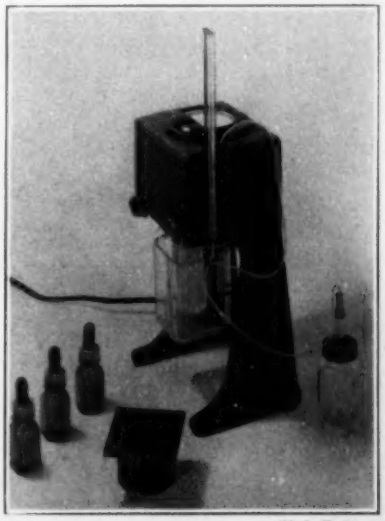
Fig. 30—HYPOCHLORITE feeder

Positive displacement pumps are available which are driven by water meters, no electricity being required for operation. In these units, the dosage rate is governed by water flow through the meter (Fig. 27), thus automatically proportioning the treatment chemical. Where electric drive is permissible, the units may function proportional to flow by interconnecting with metering or pumping energy sources.

Lowering orifice type feeders may employ electric or spring driven clock mechanisms to lower the free end of the pipe or hose. Proportional flow will result if the electric current supply is tied in with metering or pumping equipment.

Recommendations

Hypochlorite dispensers have been found suitable for auxiliary disinfection equipment at small water and



W & T Photo

Fig. 32—AMPEROMETRIC Titrator to measure chlorine. Relative concentrations of free available and combined available chlorine can be determined.

sewage works, to function when emergencies arise in connection with the normal chlorine gas feeding system. Figs. 29 and 30 illustrate typical hypochlorinating units. It is pointed out that such stand-by equipment should be subject to regular and rigid inspection in order to insure immediate availability. Where hypochlorinators are used exclusively, installations in duplicate should be a minimum requirement. A regular schedule of greasing and inspection should be maintained, in accordance with the manufacturer's instructions.

Spare parts needed usually are few in number, but experience will indicate the desirability of having spare tubing, check valves, diaphragm faces and gaskets on hand. Constant attention to regular maintenance will contribute to improved housekeeping as well as to efficient and economical operation.

Portable hypochlorinating equipment is available and may be used to advantage in main disinfection, or to rechlorinate the distribution system during emergencies.

Booklets Available

Manufacturers of calcium hypochlorite have prepared for distribution booklets which describe in detail the uses for their product. Tabular data are included for use in disinfecting varying diameters and lengths of water mains, plus other valuable information. Following are the names and addresses of those manufacturers currently producing calcium hypochlorite:

Columbia-Southern Chemical Corp.
Gateway Center
420 Fort Duquesne Blvd.
Pittsburgh 22, Pa.

Mathieson Chemical Corp.
Mathieson Bldg.
Baltimore 3, Md.

Pennsylvania Salt Mfg. Company
1000 Widener Bldg.
Philadelphia 7, Pa.

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Fig. 33—CHLORINE residual recorders. Hackensack Water Co. plant, New Milford, N.J.
These provide a continuous record of residuals in settling basin (left unit) and in plant effluent (right unit).

Summary

Chlorine does not solve all treatment problems in the sanitary field, neither do the hypochlorites. Where chlorine is specific, however, calcium or sodium hypochlorite will accomplish the same objectives. Calcium hypochlorite has become predominately accepted as an emergency disinfecting compound and is often the material of choice for chlorination at small water and waste treatment works.

References

(1) Logan, J. O. and Savell, W. L. "Calcium Hypochlorite in Water Purification", Jour. A.W.W.A., 32:1517 (1940).

(2) Mathieson Chemical Corporation, "Hypochlorination of Water", Tech. Bulletin, 47 pages, Seventh Ed. (1951).

V—Dosage Control

THE application of chlorine, or its compounds, to water or wastes must be controlled within definite limits to insure economical and satisfactory attainment of established objectives. Chlorine is unique among water treatment chemicals, not only in its applications, but also in methods and equipment available for process regulations. Operators must be aware of the overall purposes of chlorination in order to control the processes which will achieve them.

Chlorination Objectives

Disinfection continues to be the foremost objective in chlorination of water and domestic wastes. Secondary purposes utilizing chlorine have developed, and pre-, post-, or plain chlorination may be practiced. The process has been extended from relatively simple plant effluent disinfection to include ramifications of intriguing complexity.

Disinfection

When chlorine is applied for disinfection, it would appear that measurements of bacterial destruction should

be used to indicate the success of the treatment. Unfortunately, bacteriological methods are time-consuming to the extent that results become available too late to be of practical value in dosage control.

We have been forced, therefore, to accept an intermediate scheme of chemical testing which experience has shown to be adequate. Chlorine residual values have been accepted as the basis of control in the chlorination process. Bacteriological sampling has become a matter of spot checking to determine whether or not disinfection is actually being accomplished.

For purposes of disinfection, water or sewage may be chlorinated at the effluent end of the treatment process. Sufficient dosage must be maintained to establish a chlorine residual after a definite contact time. The magnitude of the chlorine residual required is determined by bacteriological sampling as noted earlier. The degree of bacterial kill required is extremely high in the case of public water supplies. The extent of disinfection required for sewage plant effluent varies, depending on local conditions.

It should be noted that of the chlorine applied, none can be depended on for disinfection until the chlorine demand has been satisfied. It is true that certain of the products formed in satisfying the chlorine demand will exert bactericidal action, but chemical analyses do not provide close enough correlation to permit dosage control on this basis. Sufficient chlorine must be added to establish a residual known previously to have been bactericidal.

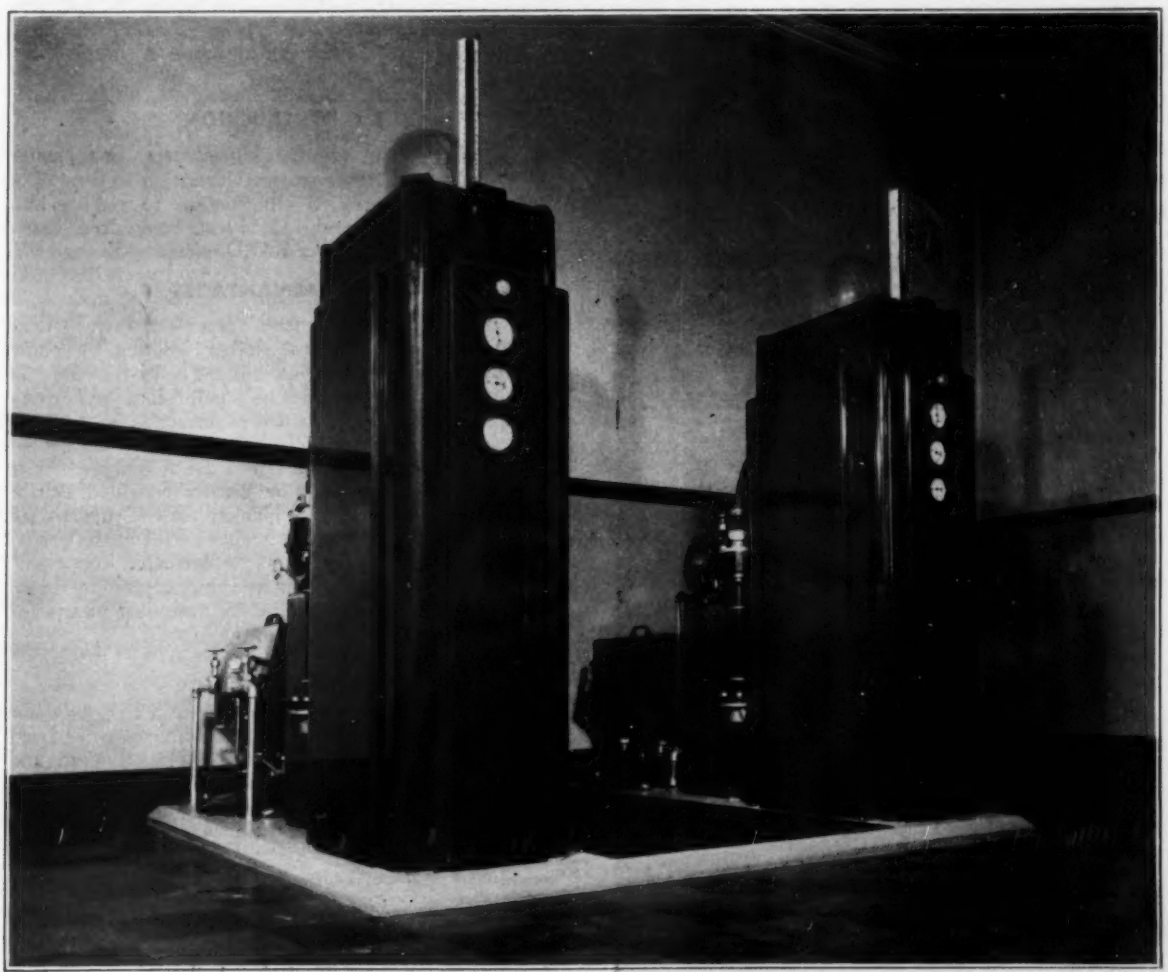
Water Chlorination

In addition to accomplishing the disinfection of water supplies, chlorine is used to control nuisance bacteria, remove iron, assist in coagulation and control tastes and odors. Dosage is controlled on the basis of chlorine residuals which are shown to accomplish the desired objective.

Nuisance bacteria may produce slime, reduce sulfates, or otherwise exist to the detriment of the water treatment process. Slime forming organisms interfere with heat transfer and restrict water flow through pipelines. Iron bacteria create nuisances often manifested in sulfide odors or in red water. Industrial process water must be free of both slime forming and sulfate reducing organisms, or product degradation may result.

Activated silica, used as a coagulant in water purification, may be prepared using chlorine as the activating agent. Chlorine used for this purpose is not lost for disinfection or other purposes.

As noted earlier, the passage of time has been accompanied by an understanding of chlorine reactions



W & T Photo

Fig. 34—AUTOMATIC CHLORINATORS. A modern installation for water treatment, Town of New Toronto, Ontario, Canada. Converter units (at rear of chlorinators) adjust chlorine dosage in proportion to water flow variations.

WALLACE & TIERNAN INCORPORATED

Manufacturers of Chlorine and Chemical Control Equipment

Belleville 9, New Jersey

"THE ONLY SAFE SEWAGE IS A STERILIZED SEWAGE"

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Bridgeport	Dallas	Kansas City	Oklahoma City	Salt Lake City	Washington, D. C.
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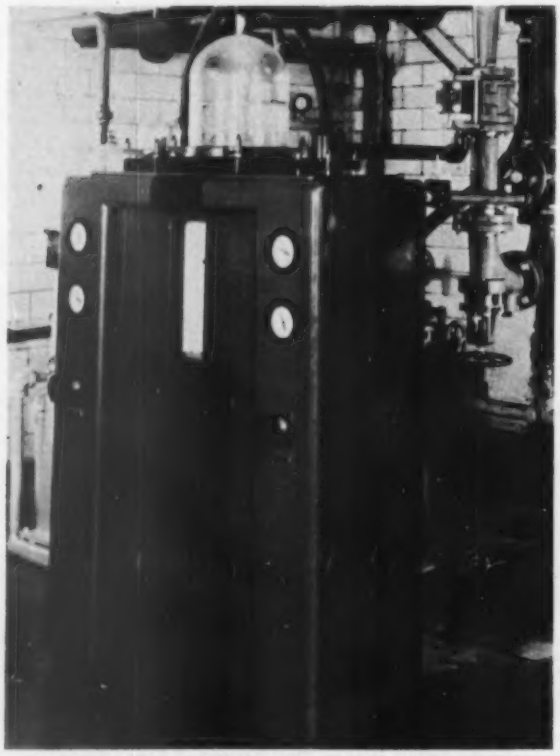
Wallace & Tiernan Ltd., Montreal, Canada
Wallace & Tiernan Ltd., London, England

DISINFECTION OF SEWAGE

The need for sewage disinfection cannot today be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of the most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.



Typical Installation of a W & T High Capacity Chlorinator Installed in a Sewage Treatment Plant.

ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

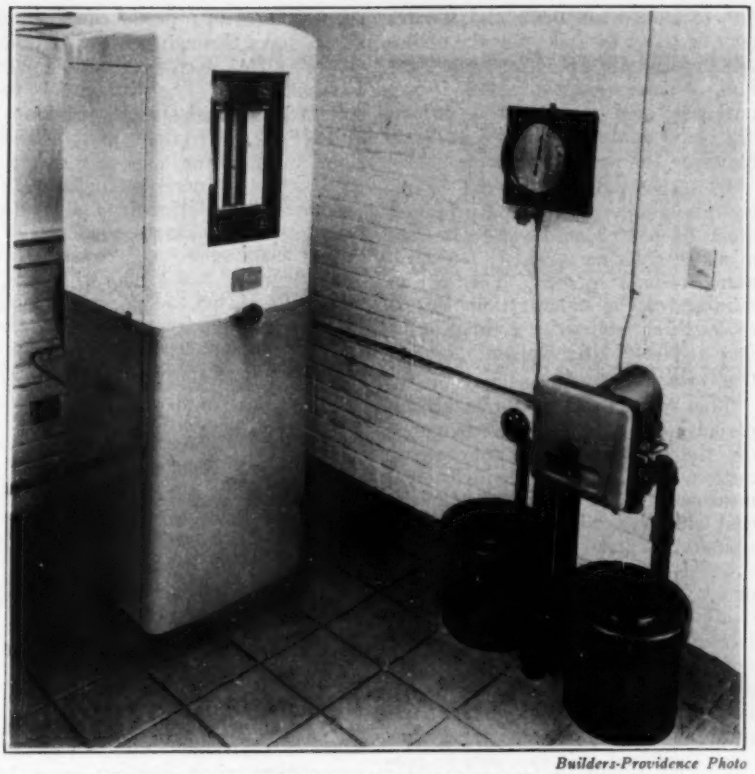
Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

EQUIPMENT

For every sewage plant, there is W&T Equipment to fit. Visible Vacuum Chlorinators with capacities from ounces to 6000 pounds per day—Solution Feed and Direct Feed Chlorinators for small plants—and Reagent and Chemical Feeders to meet many varied chemical treating applications. All W&T Apparatus is backed by over thirty years' experience and is job-engineered by chlorination specialists.

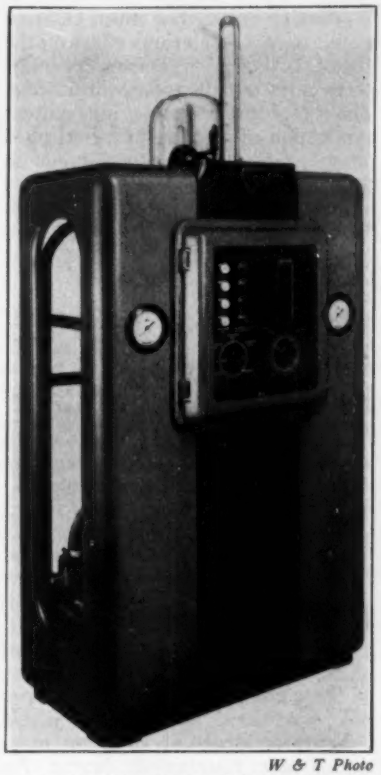
TECHNICAL INFORMATION

W&T representatives will gladly discuss any sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W&T Chlorinators will be sent free on request.



Builders-Providence Photo

Fig. 35—AUTOMATIC CHLORINIZER and Chronoflo Transmitter, Red Bank, New Jersey.
Rate of flow indicated by Transmitter and proportional dosage rate maintained by Chlorinizer.



W & T Photo

Fig. 36—PROGRAM CHLORINATOR push button type.
Other units use cam operated control.

which have added complexity to chlorination processes. Tastes and odors were found to be less noticeable when chlorine and ammonia existed together, leading to wide use of the chloramine process. However, it has been learned that while chloramines exhibit germicidal activity, they also prevent chlorine from oxidizing taste and odor producing compounds. In an effort to provide an oxidizing potential of higher order, breakpoint chlorination became the next process to receive attention and to find successful application. Superchlorination followed by dechlorination has found favor in solving particularly difficult problems in the treatment of surface water supplies.

Control of chlorine dosage in the chloramine process is effected on the basis of chlorine residuals, all or part of which may consist of combined available chlorine. Breakpoint and superchlorination processes are predicated on the establishment of free available chlorine residuals; these residuals must be of sufficient magnitude to control troublesome tastes and odors or to accomplish some other purpose. Factors of contact time, pH and temperature must be considered in the utilization of chlorine for each application.

Sewage Chlorination

Among the secondary purposes in sewage chlorination are: odor control, B.O.D. reduction, aid to settling, foam control in Imhoff units, preventing filter ponding, control of sludge bulking, assist sludge thickening, and reduce loadings caused by digester supernatant liquor return.

It is not possible for one application of chlorine to assist in solving all problems incident to sewage treatment. Upsewer chlorination can contribute to odor control and reduce the B.O.D. load imposed on the treatment works. Prechlorination at the plant entrance controls odors and might make substantial improvements in solids removal by the settling units.

Chlorination of primary settling tank effluent improves trickling filter operation, while chlorine added to return activated sludge serves to control sludge bulking. The B.O.D. loading carried to primary settling tanks by digester supernatant return may be reduced by chlorination.

Chlorine applied to trickling filter and activated sludge processes must be controlled to prevent interference with plant efficiency. Caution must be exercised when prechlorination is practiced for odor control, to control chlorine dosage so that septicity is prevented, but not to accomplish disinfection. Many operators determine chlorine demand and adjust prechlorination units to remove one-half of the chlorine demand when treating to prevent septic conditions. Other operators report that chlorine residuals must be established in order to provide effective odor control.

Odors and ponding at trickling filter plants have been controlled by chlorination. Control of chlorination to satisfy fifty to seventy-five per cent of the chlorine demand will not adversely effect the biological growth on the filter stones, but will control odors. Filter ponding, when caused by organic accumulations, may be alleviated by chlorinating the filter influent to produce 2 to 10 ppm residual chlorine at the nozzles*. Residuals in the lower range may not upset filter operation, but for ponding control, higher residuals should be attempted intermittently, such as once a week.

Chlorination at activated sludge plants to prevent sludge bulking is predicated on the selective control of biological life in the sludge returned

*Manual of Practice No. 4, "Chlorination of Sewage and Industrial Wastes. Federation of Sewage and Ind. Wastes Assns. (1951).

to primary units. Too much chlorine would have a deleterious effect on the normal biological organisms depended on to carry out the treatment process. The procedure involves intermittent application of chlorine in a controlled dosage dependent on ppm solids in the returned sludge, the rate in mgd at which sludge is returned, and on the sludge index.

Industrial Wastes Chlorination

Programs for the abatement of stream pollution have required industry to examine ways and means of controlling and treating waste discharges to prevent fouling of surface waters. Industrial wastes which respond directly to chlorination are electroplating wastes containing cyanides and chemical manufacturing wastes containing phenols. This treatment has been widely accepted since cyanides and phenols are toxic to fish life and may cause stream degradation when discharged untreated. Chlorine together with an alkali may be used to oxidize either of these compounds, provided proper pH conditions and free available chlorine residuals of sufficient magnitude are maintained during the available contact period. Chlorine dosages usually exceed the theoretical requirement due to the presence of additional oxidizable materials.

Where waste treatment plant effluent is conserved for reuse, such as irrigation or industrial process water, chlorine serves as a disinfecting agent to prevent disease transmission, in addition to oxidizing objectionable waste products.

Residual Testing Equipment

Various colorimetric procedures have been proposed for chlorine residual determination. Ortho-tolidine remains the reagent specified in Standard Methods for the Examination of Water and Sewage, and several types of commercial comparators are in use (Fig. 31). From the foregoing discussion it appears that any colorimetric method would be liable to interference from color or turbidity. The ortho-tolidine procedure does have its limitations and, while improvements have been made in the method, it falls short of the ideal technique.

If recognition is given to the limitations of the ortho-tolidine method, it may be used to make chlorine residual determinations sufficiently accurate for most purposes. Interference due to iron, manganese and nitrites may be offset by following the ortho-tolidine-arsenite (OTA) modification. When sewage contains industrial wastes of an interfering nature, the ortho-tolidine method is a poor indicator for residual chlorine.

In water purification, the breakpoint and superchlorination processes must be controlled to provide free available chlorine residuals for minimum contact perods. The ortho-tolidine-arsenite modification permits reasonably quantitative estimation of free and combined available chlorine residuals.

The Amperometric Titrator* apparently overcomes the shortcomings of the ortho-tolidine colorimetric method (Fig. 32). This instrument measures the low flow of electric current which is produced when a sample containing chlorine is titrated with a suitable reagent. Residual chlorine may be determined quantitatively, and it is possible to differentiate between free available and combined available residual chlorine by pH adjustment of the sample. The writer's experience indicates that the amperometric titrator measures more of the germicidal combined chlorine than is possible using the standard ortho-tolidine colorimetric procedure.

The Residual Recorder* represents a significant advancement in the field of sanitation (Fig. 33). This instrument provides a continuous indication of chlorine residuals and provides a permanent record of daily results. Interruptions in chlorine application and variations in chlorine demand can be announced by alarms which are available as accessories with the apparatus. Further refinements may eventually include provisions for automatically varying the application rate.

Proportional Flow Control

Trends toward instrumentation and automatic operation in industry have been evidenced in the field of sanitation. Chlorine dispensing equipment has been developed which will respond to variations in flow of the medium being chlorinated (Figs. 34 and 35). This is an important feature, one which greatly increases the efficiency of treatment and simplifies the responsibilities of operating personnel.

The operation of automatic proportioning equipment depends on pressure differentials produced when a liquid flows through a Venturi tube, orifice plate, Kennison nozzle, or Parshall flume. The differentials resulting from flow changes are transmitted to converting units which cause the chlorine dispenser to alter its dosage at a corresponding rate.

Changes in chlorine demand cannot be interpreted by automatic proportioning installations, consequently the operator must make manual adjustments to insure adequate feed of chlorine. The equipment will pace the chlorine dosage automatically proportional to liquid flow for any manual setting.

Program Control

The term "program control" is used to denote intermittent chlorine dosage according to a pre-determined schedule. Such applications include chlorination of cooling water lines for slime control and installations where pumps operate on a pre-set schedule, etc. Equipment has been developed which will permit chlorine application on an intermittent basis over a twenty-four hour period.

In program control chlorination, advance information is required so that appropriate time settings may be made to schedule chlorine dosage at a pre-selected rate over the time interval desired. Program controllers are available which operate either on a cam rotation or push button principle (Fig. 36).

Summary

Dosage control must be recognized as the foundation upon which a successful program of chlorination is built. Proper dosages for disinfection greatly exceed amounts necessary for odor control at sewage works. The amount of chlorine required to disinfect a water supply on one day (or even one hour) might fall far short of adequacy or constitute overchlorination on the following day (or hour), even though the volumes of water treated are equal.

Determinations of residual chlorine indicate whether or not sufficient chlorine has been added to establish desired conditions. Operating personnel must realize the limitations of chlorine residual test methods and, where possible, relate chlorine dosage directly to results accomplished.

Automatic devices have made substantial contributions to facilitate dosage control, but plant operators must make manual adjustments for variations in chlorine demand.

*Products of Wallace & Tiernan Co., Inc.

Measurement of Water Flow by Circular Orifice at End of Pipe

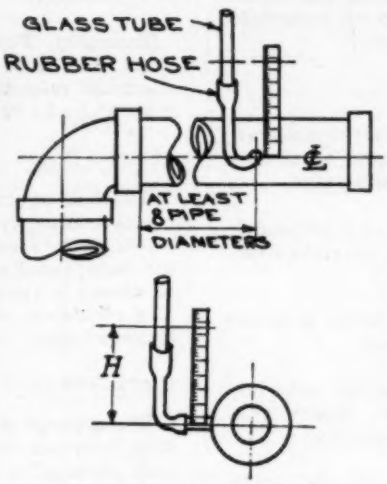
THE measurement of water flowing thru pipe lines by means of a circular orifice has been proven quite accurate, and experiments have demonstrated that a thin plate circular orifice installed at the end of a pipe line gives a rapid and accurate method for measuring such flows; the instruments being light and easily attached, permits of a simple method of testing pumping plants more accurately than the average weir that can be constructed in the field.

It is necessary that the pipe line be horizontal with no elbows, obstructions, or bends within 8 pipe diameters of discharge; the head should be measured from the center of the pipe at a point one foot or more back from the orifice.

The accompanying curve gives the discharge for 13 inch orifice on 15¼" inside diameter pipe, the formula being:

$G = KA\sqrt{2gh}$

Where G = Gallons per minute
A = Area of orifice in square inches



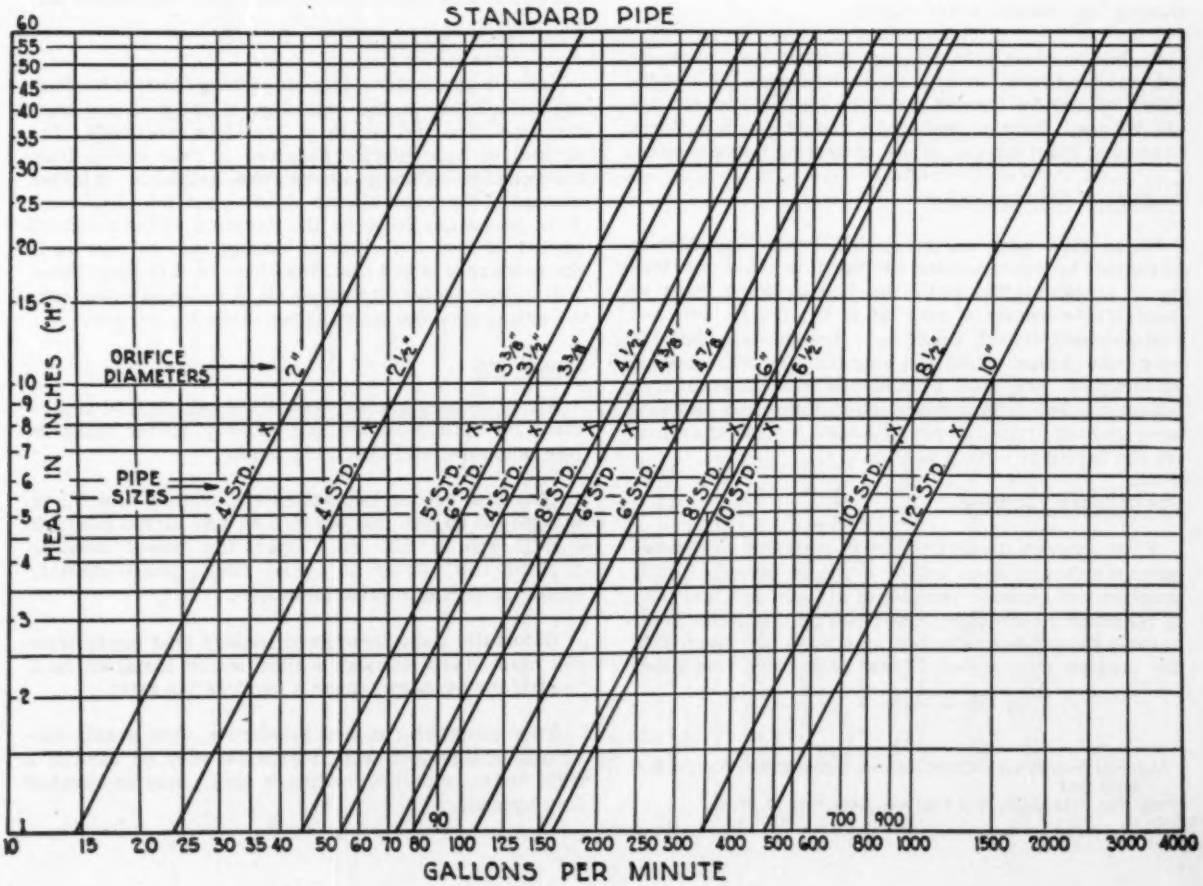
From *Peerless Pump Bulletin*

K = Constant depending on size of pipe and size of orifice.
H = Head in inches above center of discharge.

In calibrating these orifices a well constructed weir was used and the maximum variation of "K" was less than 3%. An average "K" was then taken from which these curves were constructed.

It is necessary that the orifice be running full of water and that "H" be at least one inch above top of the pipe for accurate results.

The head is measured by drilling and tapping for ⅛ in. pipe connection on the side of the discharge pipe one foot or more back of orifice, the hose connection installed and the height measured with an ordinary rule; the hole can then be plugged with an ⅛ in. pipe plug. It is very important that the ⅛ in. nipple does not extend inside the inner wall of the pipe and should be absolutely flush.



Water Main Sterilization

Recognizing the possibilities for water mains to become contaminated before and during laying and repair, the Am. Wat. Wks. Assn. has developed "A Procedure for Disinfecting Water Mains 7D.2-1946".[1]

Outline of Procedure

1. Keep interior of pipes free from foreign matter; swab interior with an effective bactericide; block open ends to prevent trench water from entering pipe.

2. Joint packing materials (in order of preference): Solid molded or tubular rubber rings, asbestos rope, treated paper rope, and braided cotton.

3. Before disinfection, flush main (after pressure test) at velocity of at least 2.5 ft. per sec.

4. Chlorinate with either chlorine or chlorine-water, calcium hypochlorite (HTH, Perchloron, Pittchlor, etc.), or liquid sodium hypochlorite.

5. Apply chlorine at one extremity of pipe section and bleed at opposite extremity of properly segregated section. Take precautions to prevent dosed water from flowing into potable water supply.

6. Inject chemicals through corporation cock or cap-cock inserted in line for that purpose. All high-points on section treated should be properly vented for air escape. Rate of application should give a uniform dose of at least 50 ppm. at end of section being treated.

Sources of Contamination

Water pipe lying on the ground before installation is subject to contamination and there is great possibility of contamination while the line is being made up. Undesirable bacteria may be in the trench soil and contaminated trench water may find its way into the open end of a pipe. Great and long lasting contamination by hemp or jute joint packing has been shown by both laboratory and field observations. Hemp and jute have been omitted from the revised AWWA "Specifications for the laying of Cast Iron Pipe".

Preliminary Flushing

Flushing prior to sterilization is desirable to remove foreign material from new or repaired mains. Actual practice has shown a velocity of at least 3 ft. per sec. is required for scouring. The chart on this Keep Sheet reveals the volume of water in gallons per linear foot for various pipe sizes. From this value, the bleed rate to obtain a flushing velocity of 3 ft. per sec. can be determined.

(Example): For a 24 in. main on Scale "B" of this chart each foot of length contains 23.5 gal. For a minimum velocity of 3 ft. per sec., the flow must be at least 23.5 x 3 = 70.5 gal. per sec. or 4230 gal. per min.

Chlorine Dose

The dose of chlorine required depends on degree of contamination, type of packing used, and pH of water. These factors must all be considered in deciding on the dose; usually the dose must approximate 100 ppm. to secure a residual of 55 ppm. at the end of the line. The efficiency of sterilization should be checked by bacteriological tests wherever possible.

Contact Period

The average sterilization period is 24 to 48 hr., but if unfavorable or insanitary conditions of installation, poor packing, or high pH exists the period may be extended to 72 hr. The rate of final removal of chlorinated water is not important but the line should be bled until the chlorine residual approaches that normally carried.

Calculations Involved

Uniform application of the sterilizing solution involves the calculation of the gallonage of the pipe line from the pipe size and length of line to be sterilized. The amount of hypochlorite required is determined from the selected chlorine dosage, the available chlorine content of the hypochlorite solution and the bleed rate. It is necessary to know the duration of the bleed-off period so that the chlorine dosage may be carried to the extremity of the line. The chart on this Keep Sheet will prove useful in making all of these calculations. An example on the chart shows steps for its use.

Equipment

Three factors are involved in the selection of equipment for main sterilization: namely, feeder capacity, line pressure, and operating power.

Chemical feeder capacities are available for 5.5 to 8.5 gph. at 85 psi.; for 5.5 to 8.25 gph. at 200 psi.; for 8 to 12 gph at 100 psi. Operating power may be 110/220 volt, 60 or 50 cycle, single phase electric motor or portable gasoline motor.

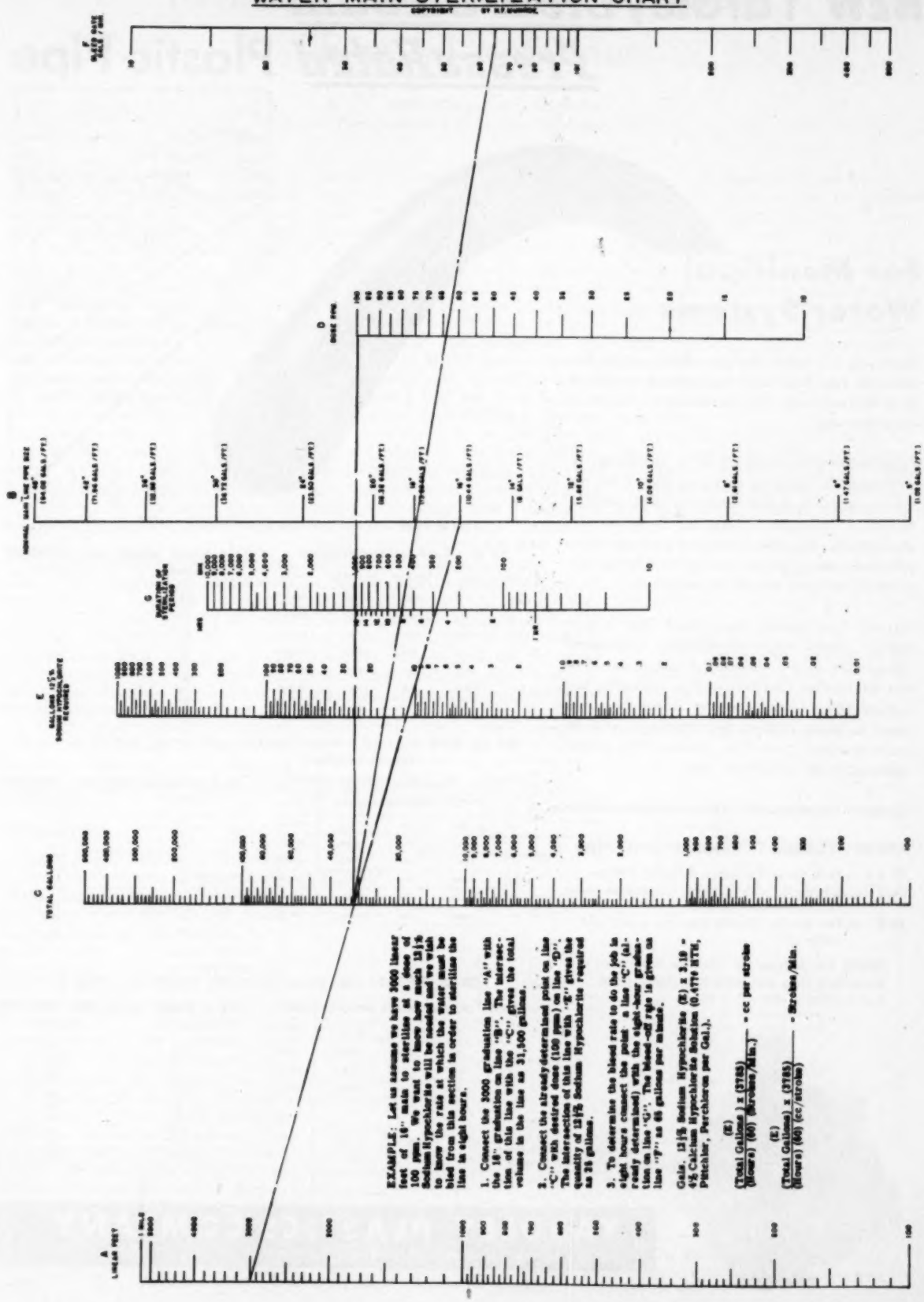
Automatic and proportional feeders take power from the main itself through a disc meter installed on a temporary by-pass around a segregating gate.

To accomplish constant bleed rate, open nozzle discharge (calculated from formulas) may be used or a Rate Setter, with flow reading in gpm., may be attached to a hydrant.

Excerpts from an article by H. Munroe in Wat. & Sew. Wks., p. R.41 April 1951.

[1] Am. Wat. Wks. Assn., 521 Fifth Ave., New York 17, N. Y.

WATER MAIN STERILIZATION CHART



EXAMPLE: Let us assume we have 3000 linear feet of 16" main to sterilize at a dose of 100 ppm. We want to know how much 15% Sodium Hypochlorite will be needed and we wish to know the rate at which the water must be bled from this section in order to sterilize the line in eight hours.

1. Connect the 3000 graduation line "A" with the 16" graduation on line "B". The intersection of this line with the "C" gives the total volume in the line as 31,500 gallons.

2. Connect the already determined point on line "C" with desired dose (100 ppm) on line "D". The intersection of this line with "E" gives the quantity of 15% Sodium Hypochlorite required as 26 gallons.

3. To determine the bleed rate to do the job in eight hours connect the point a line "C" (already determined) with the eight-hour graduation on line "G". The bleed-off rate is given on line "F" as 65 gallons per minute.

Calc. 15% Sodium Hypochlorite (E) x 3.18 = 4% Calcium Hypochlorite Solution (0.4776 HTH, Pittchlor, Perchloron per Gal.).

$$\frac{\text{(E) (Total Gallons)} \times (3785)}{\text{(Hours)} \times (60) \times \text{(Strokes/Min.)}} = \text{cc per stroke}$$

$$\frac{\text{(E) (Total Gallons)} \times (3785)}{\text{(Hours)} \times (60) \times \text{(cc/stroke)}} = \text{Strokes/Min.}$$

NEW Yardley *ClearStream* *PressuRated* Plastic Pipe

For Municipal Water Systems

Now you can *safely* design a flexible pipe distribution system to meet the pressure conditions in your community. No more doubts — no more experimenting.

ClearStream PressuRated Pipe is guaranteed to withstand the working pressures shown for the various types. It is now made for three pressure ratings — 75 lb., 100 lb. and 125 lb. in sizes ½ through 2". For your protection and easy identification, the pressure rating is continuously stamped on every length, in every size.

Yardley ClearStream PressuRated Pipe is top-quality — 100% virgin Polyethylene. Guaranteed against rot, rust or electrolytic corrosion. And like all Yardley ClearStream Pipe it handles and installs faster, easier, because it weighs ⅛ as much as steel; requires fewer fittings; cuts installation costs up to 60%; delivers 25% greater volume for the same head loss.

Complete line of necessary plastic fittings available.

Other YARDLEY *ClearStream* Pipe

M-22 — Twin-du-it, 2 pipes in 1 for Jet Pumps
M-21 — Sub-du-it, with built-in suspension cable for submersible pumps
M-2 — The quality flexible pipe for every cold water use

WRITE for Bulletin 50 showing installation instruction, flow and head loss charts, chemical resistance data.

Yardley ClearStream PressuRated Pipe in a water service line.

75 LB. PIPE—for low-pressure water systems, parks, resorts, camps.

75 LB. PressuRated SPECIFICATIONS

Size	I.D.	Nominal Wall	Weight 100 ft.	Coil Size
½"	.622	.080	7 lbs.	400 ft.
¾"	.824	.100	12 lbs.	400 ft.
1"	1.030	.125	18 lbs.	300 ft.
1¼"	1.380	.165	33 lbs.	300 ft.
1½"	1.610	.193	44 lbs.	250 ft.
2"	2.067	.230	73 lbs.	200 ft.

75 LB. WORKING PRESSURES VERSUS TEMPERATURES

Degree Fahrenheit	Working Pressure P.S.I.
– 4	128
30	121
33	117
50	99
74	73
90	62
100	52
120	33
140	29
160	15

100 LB. PIPE—for most municipal systems, golf courses, cemeteries, sprinkler irrigation systems.

100 LB. PressuRated SPECIFICATIONS

Size	I.D.	Nominal Wall	Weight 100 ft.	Coil Size
½"	.622	.110	11 lbs.	400 ft.
¾"	.824	.145	18 lbs.	400 ft.
1"	1.030	.190	32 lbs.	300 ft.
1¼"	1.380	.240	47 lbs.	300 ft.
1½"	1.610	.280	66 lbs.	200 ft.
2"	2.067	.355	110 lbs.	100 ft.

100 LB. WORKING PRESSURES VERSUS TEMPERATURES

Degree Fahrenheit	Working Pressure P.S.I.
– 4	171
30	161
33	156
50	132
74	100
90	83
100	70
120	47
140	39.5
160	20

125 LB. PIPE—for high pressure municipal and industrial applications.

125 LB. PressuRated SPECIFICATIONS

Size	I.D.	Nominal Wall	Weight 100 ft.	Coil Size
¾"	.824	.300	36 lbs.	200 ft.
1"	1.030	.330	41 lbs.	200 ft.
1¼"	1.380	.335	70 lbs.	200 ft.

125 LB. WORKING PRESSURES VERSUS TEMPERATURES

Degree Fahrenheit	Working Pressure P.S.I.
– 4	314
30	301
33	195
50	165
74	125
90	104
100	87
120	59
140	49
160	25

YARDLEY PLASTICS COMPANY
142 Parsons Ave. Columbus, Ohio • In Canada: DAYMOND CO. LTD., Chatham, Ont.

Export Sales: F. & J. Meyer, 115 Broad St., New York 4, U.S.A.

Resistant Materials for Handling Chemical Solutions

By L. R. HONNAKER and M. L. MONACK
E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

THIS paper is limited to a discussion of construction materials suitable for use with water treatment chemicals at the point of their addition. It does not include consideration of material requirements at locations elsewhere in the system. The chemicals discussed include alum, iron sulfate, activated silica, alkalis, chlorine, and fluorides.

A schematic representation of the equipment generally used for dissolving and handling some of these chemicals is shown in Figs. 1 and 2. The equipment involved in these installations consists mainly of tanks and piping. A listing of materials that are regularly used or are satisfactory for handling the chemical solutions in the strengths commonly involved is given in Table 1.

This list does not contain any new alloys or metals, primarily because no new alloys that have been developed or introduced commercially are economically attractive for use in this service. Some new high-alloy stainless materials have been developed, but they are of very little interest in this discussion. Titanium is one of the metals most recently introduced on a commercial basis, but, because of its current high cost, its use cannot be justified in the handling of these chemicals.

Rubber Lining

The excellent resistance of rubber to the chemicals used in water treatment, together with its adaptability and ease of installation and repair, makes it excellent material for lining tanks, piping, and other items of equipment. The soft rubbers that are generally used are adequate for the solutions and temperatures involved. The semihard and hard rubber compounds will generally provide somewhat better chemical resistance, particularly when the temperature is more than 150°F. Actually, however, all grades of natural and synthetic rubber lining compounds are suitable for use at temperatures up to at least 150°F, and generally up to 170°F, so that there are no temperature restrictions on the use of rubber compounds in water treatment equipment. It should be mentioned that care is necessary in handling hot, high-purity water, as it permeates rubber and causes blistering.

Rubber compounds of each of the various grades that can be applied to equipment in the plant are now available. Size of equipment or shipping conditions need not restrict the use of rubber linings. The development and extended use of the spark test to detect pinholes and discontinuities in seams and joints has done much to improve the serviceability of rubber-lined equipment. It is good practice for the plant to spark-test rubber-lined equipment when it is received from the applicator, because shipping subjects it to some abuse which might open a seam or otherwise cause a leak. At one plant, rejects have run as high as 10 per cent.

Rubber lining of equipment is accomplished through the use of calendered sheet stock and adhesives. The optimum properties of the material are then brought out by curing or vulcanizing, heat or a combination of heat and pressure being used. The lining process is sufficiently flexible to permit rubber to be used for lining almost any shape of vessel or other equipment. As a matter of general practice, equipment that can be handled by rail or truck is lined in fabricators' shops, where the rubber can be applied under controlled conditions. There are compounds available in all grades, however, that can be cured in hot water or exhaust steam. It is practical, therefore, to line tanks and other equipment in any plant or location where steam or a means of heating water close to the boiling point is available.

Rubber-lined pipe and fittings are widely used in the chemical industry to handle corrosive solutions. They are known to be quite satisfactory for handling all the solutions involved in water treatment. Flanged pipe and fittings are almost always used where rubber-lined piping is involved. Rubber compounds can be installed in standard flanged piping in sizes larger than 1½ in. This is regularly done in pipe sections up to 20 ft in length. The lining thickness is generally ⅛ in. in small-diameter pipe and 3/16 in. in the larger sizes.

Rubber-lined piping should be installed with reasonable care. The bolts

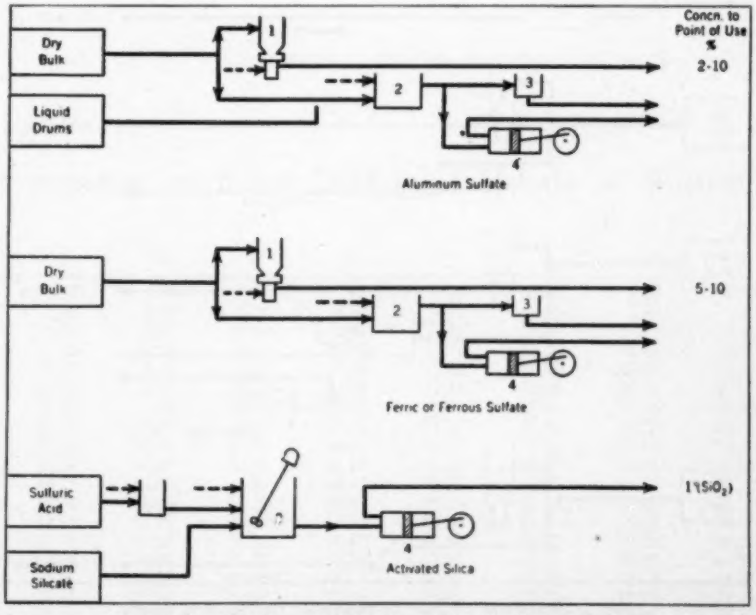


Fig. 1. Schematic Diagram of Equipment for Handling Coagulants
Key: 1—dry chemical feeder, volumetric or gravimetric; 2—dilution tank; 3—orifice type feeder; 4—volumetric pump.

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should be tightened gradually, in rotation, to avoid excessive localized stresses, and the bolt pressure should not exceed that required to maintain a tight joint at operating pressure. A number of vendors can now supply rubber-lined fittings and pipe of standard length from stock. Where special lengths are required, shipment can generally be obtained in approximately two weeks.

A drawback to the use of rubber-lined piping, particularly where time is important, is the necessity for detailing the layout to the exact lengths of pipe required. In this connection, it is of interest to mention a special type of joint that makes it practical to cut standard lengths of rubber-lined pipe to required size in the field and make flanged joints. It is possible to use adapter flanges and gaskets to permit this type of flanged end to be joined to a standard flanged end. The vendor currently carries the pipe and fittings in stock and will cut pipe to desired length and prepare ends prior to shipment, if desired.

Table 1

MATERIALS WITH SUITABLE CHEMICAL RESISTANCE

Material	Alum	Iron Sulfate	Activated Silica	Alkalis	Chlorine Water	Fluorides
	S = Suitable					
Steel or cast iron	—	—	S	S	—	—
Brass and bronze	S	—	S	—	—	—
Type 316 stainless	S	S	S	S	—	—
Type FA20 stainless	S	S	S	S	—	—
Lead	S	S	S	—	—	—
Rubber	S	S	S	S	S	S
Polythene	S	S	S	S	—	S
Uscolite	S	S	S	S	S	S
Polyvinyl chloride	S	S	S	S	S	S
Vinylidene chloride	S	S	S	S	S	S
Phenolic resins	S	S	S	—	S	S
Furan resins	S	S	S	S	S	S
Glass and glass lined	S	S	—	—	S	—
Porcelain and stoneware	S	S	—	—	S	—
Wood	S	S	S	—	—	—

Liquid Neoprene

A high-solids-content liquid neoprene material can be used to line or coat equipment by brush or spray application. This material can be applied as a liquid to a thickness of 0.01-0.02 in. per coat. By multiple applications, reasonably thick, impervious, chemically resistant linings can be formed. A putty is also available for trowel application. Heatless curing takes place through the action of a chemical accelerator which is added prior to application. Drying time between coats is approximately an hour and the completed coating can be used approximately 48 hours after application of the last coat. When the coating can be heated to 180°F, curing can be completed in approximately 2 hours.

The liquid neoprene compounds have proved quite useful and satisfactory for lining or coating miscellaneous fittings and other items of relatively small size. They can generally be considered as a substitute for rubber linings in handling water treatment chemical solutions. It is not intended to imply that the liquid neoprene is as good as a sheet-rubber lining, but its availability does make it possible to avoid delays incidental to the procurement of standard or custom-built equipment. The neoprene materials can also be used to repair damaged natural-rubber linings.

Liquid neoprene can also be used as a sealer for wood stave tanks. If properly fabricated, such a tank is very satisfactory. It is necessary to allow for the thickness of the neoprene sealer.

Plastic Piping

Plastic piping is being more and more widely used as a replacement or alternative for metal piping, especially when low pressure and moderate temperature are involved. Where plastic piping and tubing have been used within their limitations and where due consideration has been given to proper installation and support, they have provided good service. Several plastic piping materials currently available can be used for handling water treatment chemical solutions. Table 2 lists these in the order of approximate cost. Some information is shown also for metal piping, to provide a standard of comparison.

It is always misleading to compare the purchase cost of materials, particularly piping materials, when the installed cost is an important consideration. Sometimes a factor of ten in the purchase cost of piping materials may be reduced to a factor of four or less in the installed cost. Installation requirements are all-important and frequently the governing factor in the installed cost of piping.

Polythene pipe and tubing, available from several manufacturers, is a relatively new thermoplastic product which has proved reasonably satisfactory for handling many chemical solutions. It is available in either black or natural color. Chemically it is suitable for handling all the solutions that this discussion covers. Its physical properties are relatively unsuitable,

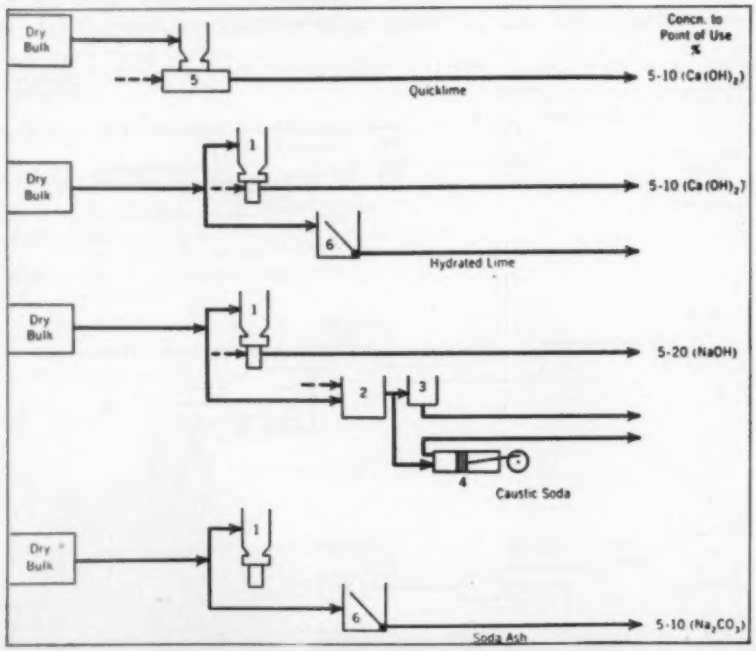


Fig. 2—Schematic Diagram of Equipment for Handling Alkalis

Key: 1—dry chemical feeder, volumetric or gravimetric; 2—dilution tank; 3—orifice type feeder; 4—volumetric pump; 5—continuous lime feeder and slaker; 6—wet chemical mixer and feeder.

Table 2

COST OF PIPING MATERIALS

Material	Cost 1-in. Pipe $/ft	2-in. Pipe $/ft	1-in. 90-deg Ell $	1-in. Tee $	Standard Pipe Length ft
Carbon steel	0.15	0.35	0.79	1.19	20
Cast iron	.....	0.56	.....	.....	5
Polythene	0.21	0.48	1.22	2.02	200
Saran*	0.60	1.20	1.01	1.26	10
Hard rubber	0.77	1.65	2.00	2.60	10
Uscolite†	0.88	2.08	1.50	1.74	10
Boltaron 6200‡	0.83	1.60	2.96	3.82	10
Lead (⅛-in. wall thickness)	1.00	1.80	.....	.....	20
Red brass (85-15)	1.04	2.33	0.61	0.87	12
Lead-lined steel (⅛-in. expanded, flanged)	1.50	2.70	8.50	10.42	20
Saran-lined steel	1.54	2.64	14.19	19.80	10
Haveg 41 (flanged)*	1.97	3.07	8.06	10.45	10
Rubber-lined steel (⅛-in. thick, flanged)	2.30	2.86	13.20	20.18	20
Lead-lined steel (⅛-in. homogeneous, flanged)	2.25	3.49	8.50	10.42	20
Type 304 stainless (welded, Schedule 40)	2.12	3.81	1.84	2.22	17–21
Type 316 stainless (welded, Schedule 40)	2.84	5.31	1.80	2.45	17–21
Carpenter No. 20 (welded, Schedule 40)#	5.03	9.83	3.12	4.22	17–21

*Dow Chemical Co., Midland, Mich.
†U. S. Rubber Co., Providence, R.I.
‡H. N. Hartwell & Son, Inc., Boston, Mass.
*Haveg Corp., Marshallton, Del.
#Carpenter Steel Co., Union, N.J.

however, and it must be supported continuously in much the same manner as is required for lead.

Joints may be made by the use of welded-on flanges, but the cost is currently high. Flanged joints, therefore, are used only when other types are not practicable. The joining of tubing is most commonly done with inserted nipples and hose clamps, but satisfactory joints can be made by welding. When inserts are used, consideration must be given to the corrosion resistance of the insert material. Another method of joining that has given satisfactory results is to use polythene sleeve fittings with a length several times the bore dimension. These are first heated in boiling water and are then forced over the pipe or tubing ends. The ends of the sleeve are then fillet-welded to the pipe. This type of connection provides better bursting strength than butt-welded joints.

Uscolite,* another thermoplastic material, is available as rigid piping in approximately standard iron pipe sizes of ½–2-in. diameter in 10-ft lengths. It has a long-term test tensile strength of approximately 1,200 psi and a relatively good impact strength. It is considered suitable for pressures up to approximately 100 psi at room temperature and is chemically suitable for handling all the solutions discussed. Its upper temperature limit is approximately 170°F.

* A product of U.S. Rubber Co., Providence, R.I.

Uscolite threads readily with standard tools and can be installed in the same way as steel piping. Experience indicates that sealing compounds are not necessary but regular pipe joint compounds can be used satisfactorily. Because most plastic threaded joints have a tendency to stick after assembly, flanged joints with soft rubber gaskets should be used when occasional or frequent dismantling is anticipated. Uscolite pipe requires better support than metal pipe. It is generally recommended that horizontal runs be supported with angle irons or by similar means. When straps are used, the spacing should be at 3–4-ft. intervals. Uscolite pipe can be bent fairly easily by heating it to approximately 180°F, bending around a suitable form, and then cooling quickly.

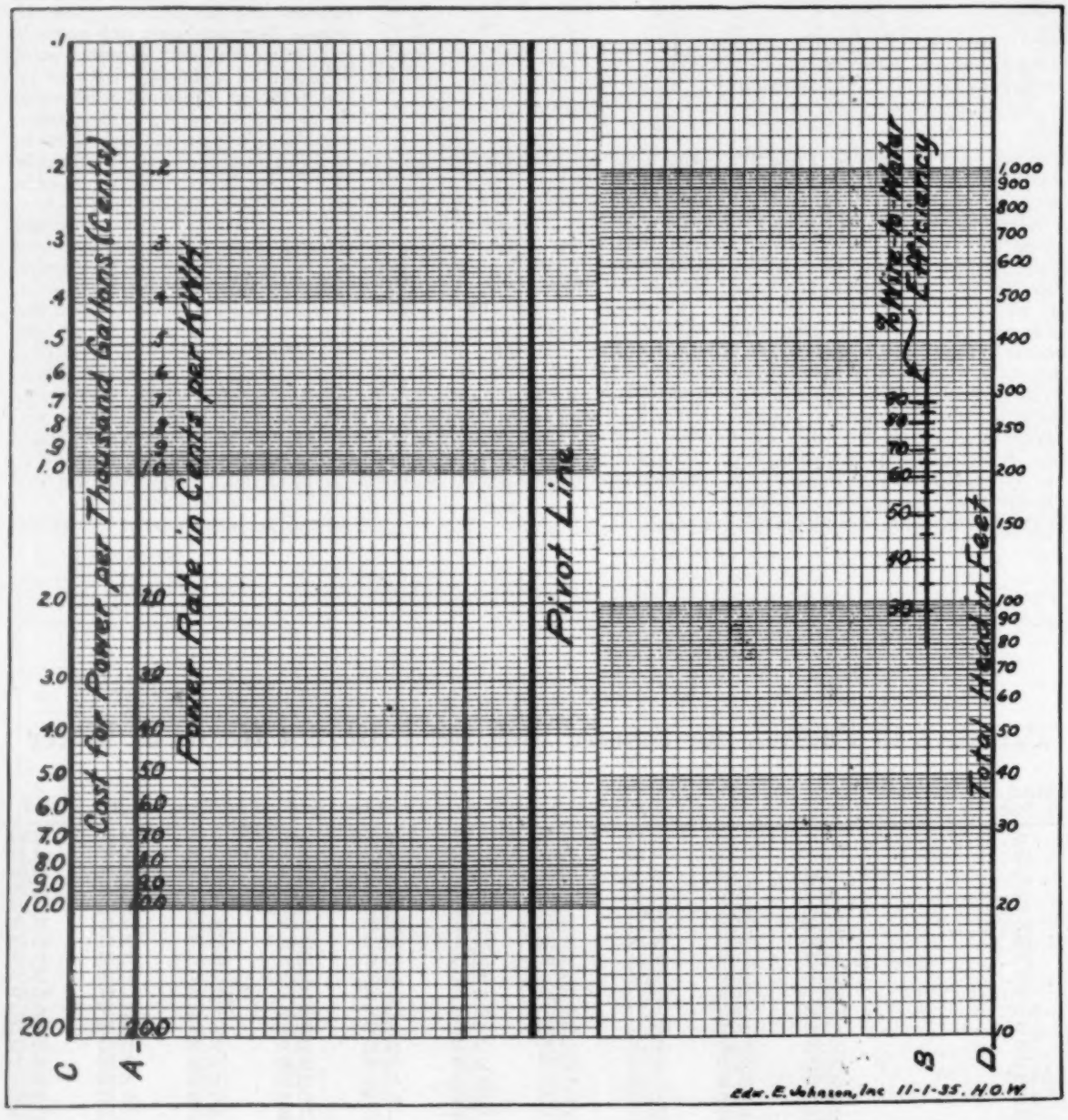
Nonplasticized, rigid polyvinyl chloride thermoplastic materials are now available from several sources as piping in standard sizes of ⅜–6-in. diameter in 10-ft. lengths. Such pipe has a long-term test tensile strength of approximately 2,000 psi and a relatively good impact strength. It is considered suitable for working pressures up to approximately 100 psi at room temperature and is chemically resistant to all the solutions involved. It can be threaded readily with standard tools and can be installed like steel, except that better support is required.

Pressure in Pounds per Square Inch for Different Heads of Water

Head In Feet	0	1	2	3	4	5	6	7	8	9
0	....	.43	.87	1.30	1.73	2.16	2.60	3.03	3.46	3.90
10	4.33	4.76	5.20	5.63	6.06	6.50	6.93	7.36	7.79	8.23
20	8.66	9.09	9.53	9.96	10.39	10.83	11.26	11.69	12.12	12.56
30	12.99	13.42	13.86	14.29	14.72	15.16	15.59	16.02	16.45	16.89
40	17.32	17.75	18.19	18.62	19.05	19.49	19.92	20.35	20.78	21.22
50	21.65	22.08	22.52	22.95	23.38	23.82	24.25	24.68	25.11	25.55
60	25.98	26.41	26.85	27.28	27.71	28.15	28.58	29.01	29.44	29.88
70	30.31	30.74	31.18	31.61	32.04	32.48	32.91	33.34	33.77	34.21
80	34.64	35.07	35.51	35.94	36.37	36.81	37.24	37.67	38.10	38.54
90	38.97	39.40	39.84	40.27	40.70	41.14	41.57	42.00	42.44	42.87
100	43.30	43.74	44.17	44.60	45.03	45.47	45.90	46.33	46.77	47.20
110	47.63	48.07	48.50	48.93	49.36	49.80	50.23	50.66	51.10	51.53
120	51.96	52.40	52.83	53.26	53.69	54.13	54.56	54.99	55.43	55.86
130	56.29	56.73	57.16	57.59	58.02	58.46	58.89	59.32	59.76	60.20
140	60.62	61.06	61.49	61.92	62.35	62.79	63.22	63.65	64.09	64.52
150	64.95	65.39	65.82	66.25	66.69	67.12	67.55	67.98	68.42	68.85
160	69.28	69.72	70.15	70.58	71.02	71.45	71.88	72.31	72.75	73.18
170	73.61	74.05	74.48	74.91	75.35	75.78	76.21	76.64	77.08	77.51
180	77.94	78.38	78.81	79.24	79.68	80.11	80.54	80.97	81.41	81.84
190	82.27	82.71	83.14	83.57	84.01	84.43	84.87	85.30	85.74	86.17
200	86.60	87.04	87.47	87.90	88.33	88.77	89.20	89.63	90.07	90.50

Chart for Determination of Pumping Costs

This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency and power rate are known. In using this chart a ruler is placed from line A (Power Rate in Cents per Kilowatt Hour) to line B (% Wire-to-Water Pump Efficiency). A pin or pencil point is placed against the edge of the ruler on the Pivot Line and the ruler is then pivoted to the proper point on line D (Total Head in Feet). The Cost for Power per Thousand Gallons can then be read directly from line C at the left of the chart. *(Courtesy Edward E. Johnson, Inc.)*

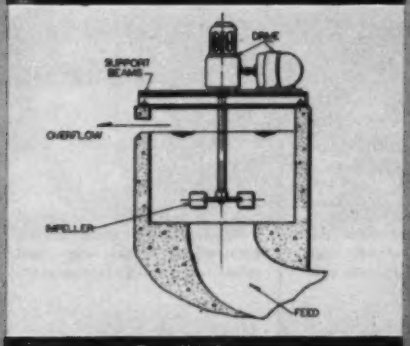


Dorr

DORRCO

Equipment and Methods for Modern Water Purification and Sewage and Industrial Waste Treatment

An outline of the major equipment units of the complete Dorr line for municipal and industrial application arranged in flowsheet order.



EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
WATER PURIFICATION		
PRE-SEDIMENTATION		
Dorr Pre-sedimentation Thickener Up to 50 MGD and 10,000 tons solids per day per unit.	Raking mechanism for circular tank, designed to collect and concentrate settled material to a central discharge cone.	Particularly adaptable where turbidity exceeds 1,000 ppm. Use results in chemical savings and reduced load on secondary basins.
MIXING		
Dorreo Flash Mixers From 0.5 to 40 MGD per unit. Bulletin No. 6971	High-speed, motor-driven mixing unit equipped with turbine-type impeller for intense mixing in few seconds.	Whenever complete diffusion of chemicals through raw water is desired instantaneously to avoid floc formation in mixing chamber proper.
FLOCCULATION		
Dorreo Flocculator* From 0.1 MGD up. Bulletin No. 6971	Motor-driven revolving paddle wheel elements set in rectangular basin. Gentle mixing causes build-up of uniform flocs of excellent characteristics.	Whenever finely-divided or semi-colloidal solids are present in raw water, the use of Dorreo Flocculators will increase plant capacity and reduce chemical consumption.
CLARIFICATION		
Dorr Clarifiers and Monorakes* From 0.1 MGD to 30 MGD per unit. Bulletin Nos. 6191 and 6001	Both center-shaft and center-pier Dorr Clarifiers equipped with rotating raking arms for round or square tanks. Dorreo Monorake is a balanced raking mechanism for use in rectangular tanks.	Continuous removal of settled solids from clarified raw water, sewage or industrial waste.

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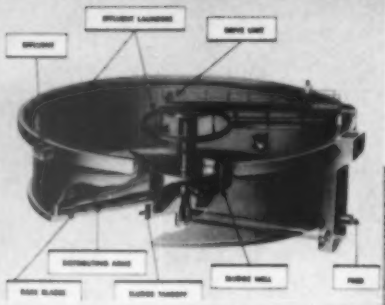
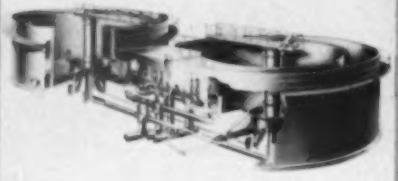
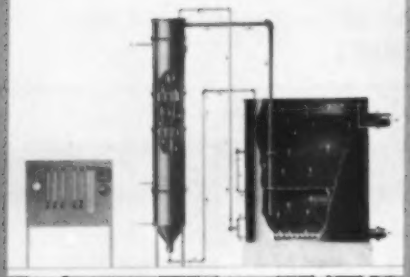
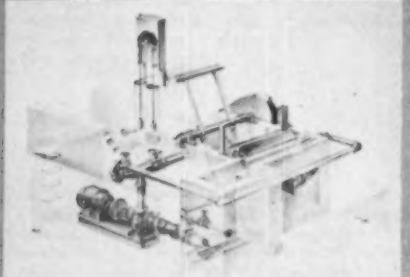
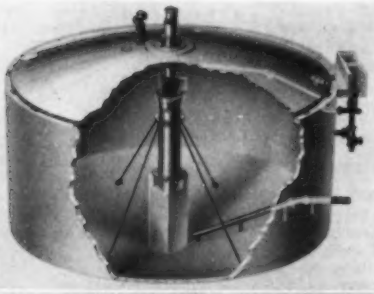


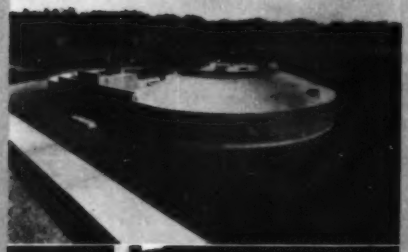


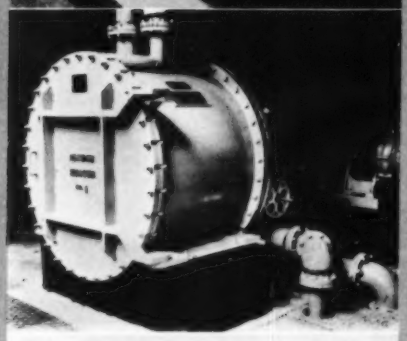


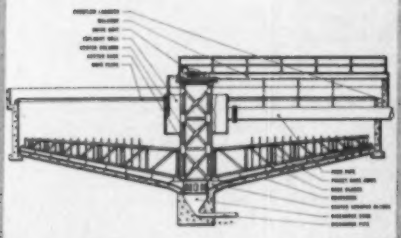


EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
COMBINATION UNITS		
Dorrco Hydro-Treator® From 0.2 to 30 MGD per unit. Bulletin No. 9041	Complete, self-contained high-rate unit providing for flocculation, thickening, clarification and positive sludge removal in a single tank.	For softening, color or low turbidity removal.
Dorrco Clariflocculator®	See sewage and industrial waste treatment.	
Dorrco Aldrich PeriFilter System From 0.1 to 5.0 MGD per unit. Bulletin No. 9042	Normally consists of two or more Dorr pre-treatment mechanisms each surrounded by an annular rapid sand filter.	For chemical pre-treatment followed by sand filtration to remove turbidity, color and hardness.
ION-EXCHANGE		
Dorrco Hydro-Softener From 75 to 800 GPM. Bulletin No. 4083	Uses base or cation exchange resins for continuous softening. Resin is continuously regenerated with brine.	For softening comparatively clear water to make it satisfactory for usual domestic needs.
SEWAGE AND INDUSTRIAL WASTE TREATMENT		
SCREENING AND GRINDING		
Dorrco Bar Screen Up to 75 MGD per unit. Bulletin No. 6400	Mechanically operated automatically activated unit consisting essentially of bar racks cleaned by motor-driven rake.	Every sewage and industrial waste treatment plant where removal of sticks, rags and other large solids is required.
Dorrco Sulzer Disintegrator 60 cu. ft. of screenings per hour. Bulletin No. 6400	Motor-driven, heavy duty screenings macerator. Consists of low-head pump with fixed and rotating cutting blades arranged in front of a perforated screenings plate.	For the maceration of sewage screenings. Especially adaptable in combination with Dorrco Bar Screen.
GRIT REMOVAL		
Dorr Detritor® From 0.25 to 140 MGD per unit. Bulletin No. 6411	Continuous, mechanically operated grit chamber consisting of separate grit collecting and grit removal and washing mechanism.	For the removal of grit of 65 mesh or coarser from raw sewage or industrial waste.
CLARIFICATION		
	See water purification.	









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EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
COMBINATION UNITS Cont'd.		
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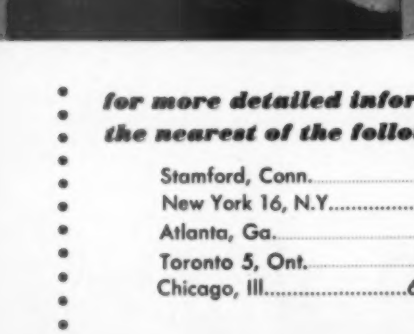 **Dorr Duo-Clarifier Duo-Filter and Duo-Clarigester** From 0.1 to 1.25 MGD per unit. Bulletin No. 7312	The "Duo" units are designed for two-stage treatment in a single structure. The Duo-Clarifier provides primary and secondary clarification in one tank; the Duo-Filter consists of two stages of filters arranged concentrically; the Duo-Clarigester provides two stages of clarification plus separate sludge digestion in a single structure.	Particularly adaptable for treatment of domestic sewage from small communities and isolated establishments with contributing populations of over 500 and industrial wastes requiring biological treatment.

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Water Supply and Pollution Control

By RICHARD D. HOAK
Senior Fellow, Mellon Institute, Pittsburgh, Pa.

AN abundant supply of good water is more than an amenity: neither life nor industry can exist without it. An individual can survive for a month or more without food, but dies in a few days if deprived of water. Industry likewise cannot flourish without the water required by its enormously diverse and complex operations.

Rivers, lakes, and ground water comprise a natural resource of primary importance to our well being; together, they supply the water that civilization needs for its manifold activities. Rivers play an especially useful role in world economy. They provide broad highways for transporting raw materials and manufactured goods. They convert swamps into arable land by draining off surplus water, and they carry away excess rainfall. They are used to develop electric energy, and they yield water to irrigate land that would otherwise be unfruitful. They assimilate much of the debris of civilization, and thus permit the growth of large urban centers. Finally, they satisfy the increasing recreational needs for a people whose science and industry steadily create more leisure time for everyone who works for a living.

It is probable that rivers were used for navigation long before the era of recorded history. Through the ages they have been used to promote the exchange of goods, and even today they are the main commercial channels in many parts of the world (6). There is excellent evidence (18) that irrigation has been practiced from the time early man first congregated in agrarian communities. The Code of Hammurabi (5) provided for regulation of irrigation to prevent flood damage due to negligence. It also placed responsibility upon local interests for maintaining dikes to protect against overflow of rivers (6). This great legal monument (*c.* 1900 B.C.) codified laws under which highly civilized societies had lived for centuries. The widespread use of rivers for water power is a product of the machine age, there being no evidence that water was used extensively for power until modern times. Flowing water has always been used as a convenience for disposing of wastes. This practice was rarely objectionable until installation of municipal sewer systems began about a century ago. As centers of population expanded, the increased volume of sewage and industrial waste caused serious stream pollution problems. It is the purpose of this paper to discuss various aspects of the relationship between water supply and pollution control.

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Distribution of Water

The water on the surface of the earth, and the free water in its crust, comes from rainfall. It is obvious then, that the amount of precipitation on a region depends upon the climate it enjoys. Data from major parts of the United States indicate that there has been a gradual decrease in precipitation and increase in temperature over the past 50 years, but there is no reason to believe that this tendency will continue indefinitely (8). Warm, dry periods have always been followed by cooler, wetter ones.

The world pattern of climate depends primarily upon the amount of oceanic cover and the size, configuration, and distribution of land masses. We are living in a period of geologic revolution that began some 30,000,000 years ago (15) (17). Crustal unrest and glaciation are features of such periods, and mankind has never experienced the "normal" climate of the geologic climatologist. Rather wide fluctuations in climate from time to time at a given place have been observed. This has led to many attempts to explain climatic changes in terms of recurring cycles, but there has been no proof that short-term fluctuations are other than random occurrences. In the present state of knowledge, therefore, long-term forecasts of the weather are impossible, and water supply projects must be planned on a basis of statistical probability.

This country does not have as wide average extremes of precipitation as occur in the rest of the world. For the world, average annual rainfall ranges from less than 5 in. in desert regions to more than 450 in. on the Assam plateau (7). The maximum rainfall recorded in one year was 905 in., of which 366 in. fell in one month (Cherrapunji, India, 1861). Extremely high rates of precipitation of relatively short duration have occurred in many parts of the world. In the United States, the annual range is from less than 5 in. in the Southwest to more than 100 in. in the Pacific Northwest. The average annual rainfall for the whole country is 30 in. (19), of which 20.5 in. quickly returns to the atmosphere through evapotranspiration, and 8.5 in. runs off to streams or percolates into the ground-water table (1). Averages can always be misleading, however, because no area is immune from occasional droughts or floods.

The United States has an area of 3,026,789 sq. mi. Assuming an average annual runoff yield of 8.5-in., the water available for all uses would be 4.5×10^{12} gal. per year. This compares with an estimated daily requirement for all water needs, including irrigation, of 1.7×10^{12} gal. The fact that the average water yield from rainfall is about 7 times the daily need shows how abundantly this country is supplied, but it obscures the significance of rainfall distribution. The water supply problems of the United States result largely from poor distribution of water, both in time and place. The diversity of water supply is well illustrated in Table I (3), which compares the hydrologic characteristics of Maine, Ohio, and Arizona with the average for the nation.

Ground water is a very important factor in water economy. It not only provides the water that is withdrawn from wells, but it regulates the flow in streams. It has been estimated that between one-third and two-fifths of the rainfall runoff has passed through ground-water reservoirs before entering streams (8).

Water Requirements

It has been estimated that an average of 170,000,000,000 gal. of water was withdrawn daily from the ground, streams, and lakes in 1950. An additional 1,100,000,000,000 gal. was used to generate hydroelectric power.

An accurate estimate of the net withdrawal of water is quite difficult. Considerable water is withdrawn, used, and discharged to a stream, or to the ground, only to be withdrawn again. In a number of instances the entire flow of a stream is used several times by successive establishments. The estimated withdrawals of surface and ground water in 1950 are listed in Table II (11). The estimate of municipal use is probably the most

Table I
VARIATIONS IN WATER AVAILABILITY

Item	Maine	Ohio	Ariz.	U.S.
Av. annual rainfall (in.)	40	38	14	30
Av. annual yield (in.)	25	12	0.7	8.5
To streams and aquifers (%)	63	32	5	28

accurate, and that of industrial use the least. Some water has been counted several times, because each withdrawal was added to the accumulated total without regard to previous use upstream. Water recirculated in a plant, and therefore used several times, was counted only once.

Industrial plants using in excess of 10 m.g.d. account for 80 per cent of industrial water withdrawals (20). Among large users, more than 50 per cent of the water intake is used for cooling. In the steel industry, for example, it is estimated that roughly 75 per cent of its large water withdrawal is used for cooling alone. By contrast, only about 25 per cent of the water requirement of small enterprises is used for cooling.

A selected list of industrial water usages, in terms of manufacturing units, is given in Table III (10) (13) (20), which discloses the great variation in the water requirements of different industries, even though the customary production units are not directly comparable. Of more significance is the revelation of wide differences among manufacturers of similar products. Although water consumption is related to product quality and type of process, opportunities for a reduction in water usage appear to be evident.

The heaviest consumer of fresh water is irrigation. In 1950, the 26,000,000 acres of irrigated land in the United States received about 50 per cent of the fresh water withdrawn (3), and nearly one-third of this huge volume came from wells. Although some of this water percolates into ground-water reservoirs or runs off to streams, most of it is evaporated directly or transpired. Irrigation is a relatively uneconomic use of water. There are some 20,000,000 acres of potentially irrigable land in the West, but the steeply rising cost of bringing water to such regions suggests that the available water should be applied to more productive uses.

Municipal use of water is small, as compared with the volume needed in irrigation and industry. In 1950, municipal consumption of water averaged 145 g.p.d. per capita, but this figure includes water for fire protection, street flushing, business, and manufacturing. Most of the water used for air-conditioning is drawn from private wells, because such water normally has a lower temperature than the community supply. The increasing popularity of automatic washing machines and domestic air-conditioning units may presage a time when the demand on public supplies will expand considerably.

In a technical sense, the use of water for generation of hydroelectric power might be considered a withdrawal use. But the water is withdrawn for only the brief time needed for it to pass through the turbines. Except for abstraction of a portion of its potential energy, it is no way altered. Generation of power from water, however, indirectly results in a consumptive use through evaporation from the reservoirs impounded behind power dams. Loss of water by evaporation is a function of a number of factors, among which are the temperature of the water, the humidity of the air above it, insolation, wind velocity, and atmospheric pressure. A number of empirical formulas have been derived from experimental studies for estimating evaporation loss, but data from actual impoundments are scanty. That loss of water in this manner may be very large is revealed by observations made on bodies of water in Texas and Arizona. The average of three sources of data show losses ranging from 2.6 to 9.8 in. per month (January and July) (6).

Nonwithdrawal Use of Water

Water has a high economic value for several important uses that do not require it to be withdrawn from streams. Among these are navigation, recreation, wildlife conservation, and waste disposal.

The economic importance of waterborne commerce is shown by the comparison of various means of freight transport given in Table IV (14).

Recreational use of surface water provides an anodyne for the strains of modern living. American industrial technology constantly strives to produce better goods at lower prices. This industrial objective steadily raises standards of living, including an abundance of leisure time. Fishing, swimming, boating, and camping provide opportunities for salutary use of leisure, but such activities require clean water for healthful enjoyment. A state can have no more valuable asset than appealing recreational areas. This is demonstrated by the growing economic importance of the tourist industry. Commercial fishing is a significant factor in the economy of several states, and wildlife propagation benefits the national interest.

Table II
ESTIMATED WITHDRAWAL USE OF WATER, IN BILLION GALLONS PER DAY

Use	Ground Water	Surface Water	Total	%
Rural	2.858	0.706	3.564	2
Municipal	3.584	10.056	13.640	8
Industrial	5.525	59.326*	64.851	38
Irrigational	20.204	68.486	88.690	52
Total	32.171	135.574	170.745	100

* Fresh water only; in addition, 12.635×10^9 gal. of brackish water were used by industry.

The use of water for final disposal of liquid wastes is an essential one. Large communities could not exist if streams or tidewater were not available to carry away their waste water. There is nothing improper in this method of waste disposal, but difficult problems arise when water is called upon to assimilate a volume of waste that exceeds its capacity for self-purification. When streams are overtaxed with pollutants, the water becomes unfit for other uses. This is a wasteful use of a valuable natural resource. Streams flowing through industrial regions should not be expected to carry water of the same quality as those draining agricultural land. But there is rarely a valid excuse for permitting streams to become so degraded that they are an offense to common decency. Good citizens all agree that pollution should be controlled. Nevertheless, development of controls that truly serve the best public interest is a difficult technical problem.

Stream pollution, as a national problem, did not occur suddenly. It has increased more or less gradually, sometimes almost imperceptibly, over the past century. Actually, the jobs created by industrial expansion were much more important to the public than any pollution that might result. Twenty-odd years ago, however, the general public became aware that stream pollution had become a serious problem in many parts of the country. Aroused groups demanded and got legislation to halt stream degradation.

Some laws wisely gave a sensible degree of discretion to the regulatory agencies they established; the requirements of others were too rigid for strict enforcement. Rational control of stream pollution can be exercised only by a thorough understanding of the many technical, economic, and societal factors that affect the public interest. The strenuous activity of numerous untutored groups has understandably resulted in considerable misdirected effort.

Two significant facts were apparently forgotten in the clamor for

Table III
INDUSTRIAL REQUIREMENTS FOR WATER

Industry	Unit	Water (gal./unit)
Beverage:		
Beer	Bbl.	298 to 2,500
Soft drink	Case	2.5
Whiskey	Gal.	80
Canning (all kinds)	Case[1]	3 to 250
Coke	Ton	3,600
Dairy: Milk, cream, butter	100 lb.	11 to 25
Gasoline	Bbl.	357 to 1,050
Manufactured ice	Ton	240 to 9,000
Oil refining	Bbl.	770
Paper:		
Paper and paperboard	Ton	39,000 to 90,000
Pulp (all kinds)	Ton	5,000 to 85,000
Power:		
Electric	Kw.-Hr.	52 to 170
Steam	Ton coal	60,000 to 120,000
Slaughterhouse	Hog	5.5 to 11
Soap	Ton	500
Steel (finished)	Ton	65,000
Sugar Refining:		
Cane	Ton	1,000 to 28,000
Beet	Ton	24,000 to 34,000
Tanning	Lb.[2]	8
Textile:		
Cotton goods	Lb.	28 to 40
Woolens	Lb.	70
Rayon yarn	Lb.	125 to 200

[1] No. 2 cans.
[2] Pounds of raw hide.

stringent legal measures. In the first place, laws alone are inadequate to bring about pollution abatement. Stream pollution is such a complex problem, with so many diverse ramifications, that no rational person could expect it to be legislated out of existence. It is easy to demand that pollution cease forthwith; it is difficult to explain how this can be done. Legal restraints were fought for by well-intentioned, but often ill-informed, conservationists. Too frequently they were so busy saving other people's rivers that they could not see the discharge of raw sewage from their own communities. The customary reluctance of municipalities to install sewage treatment plants is well-known, and even understandable. The hesitancy of governments to require compliance with the law in such cases is equally understandable, although more discreditable, because it is often based on political considerations. Under such circumstances, industry could scarcely be expected to be enthusiastic about building costly plants to treat its waste waters. Fortunately, the mistrust that was generated by inequitable enforcement of anti-pollution legislation in years past is slowly disappearing. This has come about through recognition of the fact that the source of pollution has no bearing on its effects. As a result, as much pressure is gradually being exerted to abate pollution from domestic sewage as from industrial wastes. More significant is the increasing degree of cooperation between industry and regulatory agencies in an effort to understand each other's problems. This approach to a difficult situation is one that should have been adopted long ago.

In the second place, many conservationists seem to hold the curious idea that conservation is synonymous with saving through non-use. They regard the discharge of any kind of waste water into streams as a sort of desecration. True conservation means productive use of natural resources for the common benefit. Forests of the United States provide an instructive example of productive use of a renewable resource. The wasteful timbering operations of the past are rarely practiced today. Modern silvicultural techniques have demonstrated that woodland can yield more timber than formerly, and, at the same time, keep forests healthier than they were before their trees were cut. In the same way, streams can perform their necessary economic function of assimilating wastes, without destroying their value for other uses.

What Is Stream Pollution?

Pollution is difficult to define precisely. This is due partly to the lack of knowledge, and partly to the fact that definitions usually reflect the aims of those who do the defining. But all definitions contain the basic idea that pollution really means the presence of so much of something in streams that it interferes with their use for a particular purpose. It is this concept that causes trouble for the definition-makers. What is called pollution under one set of conditions would not be considered to be pollution under different conditions. Definitions of pollution thus derive from priorities of stream uses, and these depend upon stream location. Therefore, no universally applicable definition is possible. All-inclusive definitions are convenient administrative devices, however, and some laws contain them. If improvement in water quality is the objective of anti-pollution legislation, rigid definitions should be avoided. They prevent the flexibility in appraisal of effects that is essential for control of pollution in the broad public interest. Too often they become substitutes for thoughtful analysis of difficult problems.

Definitions must be simple if they are to be both equitable and effective. The problem of practical definitions was recognized by the authors of the California anti-pollution legislation when they defined three categories of pollution (2). "Contamination" means hazard to public health; "pollution" means adverse effects on other beneficial uses; and "nuisance" means damage from unreasonable disposal practices. If the basic concept behind all definitions is kept in mind, however, further simplification is not only possible, but desirable. *Pollution is the discharge of material that unreasonably impairs the quality of water for maximum beneficial use in the over-all public interest.* The latitude of such a definition requires an agency to do more than apply a set formula. It insists upon a proper determination of the maximum public interest and the unreasonableness of the impairment. It may be argued that decisions on these points would be difficult or impossible. This is the objection of a lazy mind. Any good consulting engineer can examine a given situation, determine the optimum public interest, establish the degree of correction required, and support his findings with figures instead of speculations. It may also be maintained that such a definition would hamper administration of the law and that evasions would be widespread. This is the excuse of those who prefer rules to reason. The most effective tool of anti-pollution administrators is education—not the threat of legal reprisal. Legal backing will always be needed to deal with recalcitrants, but at least one highly industrialized eastern state made remarkable progress in pollution abatement without an anti-pollution law.

Table IV
DOMESTIC FREIGHT TRAFFIC (1948)

Carrier	Traffic (10^6 ton-mi.)	Traffic (%)
Railways*	641,104	62.7
Great Lakes	118,707	11.6
Inland waterways†	43,123	4.2
Highways	100,140	9.9
Pipelines	118,676	11.6
Total	1,021,750	100.0

* Does not include express, mail, and electric railway traffic.
† Does not include coastal and intercoastal traffic.

Are Water Quality Criteria Valid?

It is rather surprising to observe the steady stampede to so-called standards of water quality. It is amazing to examine the methods sometimes used to prepare them. Many rest upon a doubtful scientific foundation, and some are purely speculative.

Standards bring a sense of comfort and satisfaction to those who adopt them. They seem to simplify difficult problems; they comprise a kind of benchmark that provides a permanent and quasi-legal datum. It is just this connotation of permanence that impairs whatever usefulness they may have. The illusion lies in their generally unsound basis, and in the usually unexpressed conviction that, once established, they need never be altered. Industry and regulatory agencies alike must share the responsibility for seek-

ing standards in the expectation that they will help solve their problems. There is an excuse for industry's desire for water quality standards, because it is accustomed to manufacturing products to strict specifications. But the agencies should know better. They should know that fixing a justifiable standard is vastly more difficult than defining pollution. It is true that few agencies have the resources or the personnel to make the investigations required to set standards of any kind, but this situation should be a warning instead of an encouragement. Instead, they often sacrifice the public interest to administrative expediency. This criticism by no means implies that regulatory agencies are insincere, or that they are not trying to do their job well. Sometimes they cannot resist public insistence on adoption of standards, and sometimes their statutes are interpreted to require them. It does suggest that they re-examine their position. As experts in stream sanitation they should guide public and legislative opinion to sound basic principles.

A little reflection will show clearly why water quality standards of the usual sort are inequitable when applied uniformly over a considerable area, such as a state. Our knowledge of the specific effects of most substances on particular uses of water is quite sketchy. Where stream ecology is concerned, dependable data are appallingly meager. The effects of synergism and antagonism on stream biota are clearly recognized, but little is known about the mechanism through which their influence is exerted. Methods for assessing the capacity of streams for assimilating organic matter are gradually being refined into practical tools. But the rates at which most other material is rendered innocuous as a result of natural phenomena are unknown. The constituents, strength, and volume of waste water vary over a wide range, and their effects are enormously diverse. In view of the uncertain knowledge of the effects of specific substances, even under controlled conditions, establishment of uniform standards for a large area cannot be in the best public interest.

Where substances are known to be toxic or to be deleterious in other ways, regulatory agencies have an unfortunate tendency to rule that such substances must be eliminated completely from effluents. Obviously, this simplifies the task of the agency's personnel, but it is just as obviously unjustifiable, either scientifically or economically. For example, one agency has ruled that cyanide must be zero in any effluent. Although soluble cyanides are toxic, even in low concentration, there is a limit below which they are harmless. It has been reported that concentrations below about 0.1 ppm. have no adverse effect on fish. Nonetheless, an industrial plant discharging waste water containing 0.005 ppm. of cyanide has been told to provide facilities for complete removal of this minute amount of cyanide, despite the fact that healthy fish can be seen daily in the pool created by the discharge. The same agency has surpassed those who have set a standard of 5 p.p.b. of phenol after dispersion in the receiving water; it requires that phenol be completely eliminated from all effluents. Phenol causes an objectionable taste in water at a very low concentration, but streams can assimilate about 1,000 p.p.b. in 24 hr. Such strict requirement is thoroughly unrealistic.

These examples illustrate the extremes to which the yearning for fixed standards can lead. It is significant that an exhaustive survey of water quality criteria, recently published by the State Water Pollution Control Board of California (21), recommended that no attempt be made to establish standards of water quality. It recommended, instead, that each pollution problem be evaluated separately in the light of local conditions. These conclusions were based upon a study of 2,350 references in the literature of water quality control. Four years earlier, the Ohio River Committee (12) had reached a similar conclusion.

Rational Use of Water Quality Criteria

It might be inferred from this criticism of standards that criteria of water quality are quite useless as means for controlling pollution. This would be a false assumption. The fallacy of stardards arises from attempts to apply them arbitrarily to large areas without considering local conditions. Streams are used for many beneficial purposes, and quality requirements vary widely at the actual point of use. The term "point of use" must be construed broadly. It may range from a public water supply intake to a relatively long stream section serving primarily for recreation. The best public interest will be served by limitations placed upon discharge of pollutants only if the quality of water required for maximum beneficial use is first established.

Setting quality criteria, even for a specific stream function, is not often an easy task. For example, Wolman (22) has called attention to adjacent states where one approves a density of *B. coli* in water for swimming which is 500 times as high as that regarded as safe by its neighbor. And Hubbs (9) has expressed the opinion that, where fish are concerned, any definite limit of dissolved oxygen would have to be set without scientific foundation.

In spite of the difficulty of reaching full agreement upon definite values for specific criteria, it is possible to choose limits, based upon a thorough survey of local conditions, that could reasonably be expected to provide water of appropriate quality for particular stream uses. The question of density of coliform organisms in water suitable for bathing could be resolved by an inspection to determine whether the bacteria came principally from fecal or from natural sources. It is known that healthy fish depend upon a varied and balanced microbiota, and knowledge of the conditions under which desirable organisms thrive would suggest a proper level of dissolved oxygen for a given stream section. In the same manner, a careful examination of the special requirements of a particular water use would lead to selection of limits that would protect that use. All that is needed is a willingness to study every situation carefully, with the intention of choosing the best possible criteria for each. The real objective of stream pollution abatement is not merely to prevent an increase in pollution, but to effect a gradual improvement in water quality. For this reason, and because of the paucity of dependable data, use of a sensible factor of safety in setting quality criteria is perfectly logical. This does not mean that criteria should be selected that will protect a stream section from every conceivable future development on its banks. Protection should be afforded only for current usage and for developments actually expected in the foreseeable future.

Procedures for Pollution Control

There would be no pollution problem if it were not for the ineluctable laws of economics. This hard fact cannot be overcome, even by the most repressive legislation. In spite of a naive illusion to the contrary, the cost of pollution abatement must finally be paid for by the public, whether treatment works are built by government or by industry. Moreover the law of diminishing returns operates as effectively in the waste treatment field as it does in business. Therefore, pollution abatement requirements should be examined in terms of their true value *versus* their real cost

to all the people. Such intangibles as esthetic appreciation and recreation cannot readily be valued in monetary terms, but it is always pertinent to inquire whether measures taken to protect them are not more restrictive than they should be. It is not generally recognized that the cost of removing a given substance from a waste usually rises exponentially as the degree of elimination approaches zero.

The only defensible way to decide upon measures to correct any pollution problem is to survey the real needs of the region in which it occurs. This means a determination of the quality of water actually required to serve the optimum local interest. It does not mean mere preservation of the *status quo*. Streams have become unnecessarily degraded in many areas, and they should be restored to a condition conconant with reasonable local aspiration. But corrective measures applicable to recreational areas can never be justified for regions that are primarily industrial. The cost of waste treatment must always be weighed against the discernible benefits it will provide.

An intensive survey of all factors affecting water usage in an area is the only sound way to decide upon measures that will provide appropriate water quality. It is obvious that defensible decisions cannot be made until data on which to base them have been collected. Such a survey should include a tabulation of the constituents of wastes being discharged currently, their quantity and normal range of fluctuation, and their geographical distribution. The assimilative capacity of the stream should be evaluated in terms of present and foreseeable loadings; this determination should take into account every factor that might exert a significant effect. The survey must also assemble dependable data on the volume of water used, who uses it, and for what purpose. Water uses that are actually expected in the immediate future should be estimated. Suitability of the water for existing needs could then be established. If the water were unsatisfactory in one or more respects, the steps that would be needed to bring about a desirable degree of improvement could be decided. Comprehensive surveys of this kind are rather expensive and time-consuming, and they must be made by competent personnel. But there is no simpler method that will yield a truly equitable basis for pollution control.

Regardless of the thoroughness of a comprehensive survey, its long-term effectiveness as a means for regulating pollution is limited by two factors. Few industries, especially in the chemical manufacturing field, can predict all their future operations with certainty, and day-to-day variations in operation are not abnormal. In addition, other waste-producing industries may wish to locate in the area surveyed. The capacity of streams for self-purification is largely a function of the volume of water they carry. This is controlled by the climate of their drainage basins, and rainfall varies considerably in most localities from year to year and season to season.

The first difficulty can ordinarily be handled satisfactorily in two related ways. When local quality criteria are to be established, values should be chosen to provide a reasonable margin of safety. In addition, provisions should be made for occasionally exceeding the criteria for a limited time. If new industries plan to locate in areas that have already been evaluated, where stream capacity is fully allocated they must be prepared to install exceptionally complete waste treatment. This may impose a serious penalty under some conditions, but the only alternative would be to force the industries that were there first to increase the effectiveness of their waste treatment. Such problems can be quite complex. They can best be settled through arbitration among local interests assisted by engineering experts.

The second difficulty can be resolved by application of statistical techniques. Although there are no reliable methods for predicting long-range climatic changes, records of past conditions provide satisfactory statistical guides to future expectations. It is economically impossible to protect a stream against every conceivable climatic condition. Rational controls must be based upon some normal value for stream flow which, in turn, will fix assimilative capacity. This normal value, which will include several factors in addition to flow rate, should be so chosen that undesirable conditions will be unlikely to occur oftener than once in a selected number of years. The tolerable frequency of occurrence of unsatisfactory conditions can be decided only by the local economy of an area. A span of 5 to 10 years is usually regarded as a sound design basis, but special circumstances may demand a longer period. Where commercial fishing is an important aspect of the local economy, for example, a design period of 20 to 30 years may be warranted.

In highly industrialized regions, allocation of assimilative capacity presents a difficult problem. One solution would be to apply the principles evolved by the Joint Committee for determining fair charges for treating combinations of sewage and industrial wastes, as outlined by Schroepfer (16). This might be done by using net assimilative capacity as the equivalent of capital, and apportioning it among the contributors in much the same way as the cost of operating a treatment plant is distributed. Camp has proposed an interesting device (4) which deserves careful study. He suggests that a public agency own and operate all treatment works in a given area, and that the contributors be assessed in terms of the cost of treating the waste from each. There would be numerous advantages in such a scheme. Industry would be relieved of the managemental distractions of building and operating treatment works, and the annual assessment could be deducted from net income as an operating expense. A public agency could finance construction of facilities with long-term, low-interest bonds; provide competent technical personnel; and deal directly with state or interstate regulatory agencies. Questions concerning relative treatment costs could be settled by arbitration, or by research, where necessary.

The procedures outlined for regulating pollution in the best public interest take time and real effort. Only a limited number of comprehensive surveys could be made in any one year, and a great many will be required. Regulatory agencies in the meantime under pressure from the laws they were appointed to enforce, would be placed in an awkward position. There is one rather simple solution to this dilemma which might result in unanticipated beneficial results.

A great deal of emphasis, especially in industrial areas, has been placed upon installation of waste treatment plants that will provide the ultimate in effluent quality. Elaborate treatment usually can be justified only where a comprehensive survey has shown it to be necessary. It frequently happens that a higher degree of treatment is insisted upon than the situation appears to require. Where convincing data cannot be cited, an industry has little choice but to accept the agency's estimate of what is needed. When a survey is finally made, it may show that the agency made an estimate based upon an unrealistic factor of safety.

The task of deciding how much treatment a given waste will need is difficult enough when complete information is available. Where data

are inadequate or wholly lacking, decisions can be no better than intelligent guesses. If the basic object of pollution abatement is to be improvement of water quality, the emphasis should be placed on the stream and not on waste treatment. Where dependable data are not at hand, it would be logical to require all establishments contributing to a specific locus of pollution to employ various preliminary corrective measures. In the beginning, such steps should be minimal. In many cases good housekeeping will result in a significant reduction of polluting material. In others, fine screening, subsidence basins, regulation of rate of discharge, chlorination, or similar relatively simple measures may be adequate. Where preliminary installations are made, they should be planned in such a way that additional treatment units can be conveniently added. Enough is known about the effects of organic and toxic substances to suggest that reasonably complete treatment be provided initially. On the other hand, no treatment should be required for isolated discharges if they do not unreasonably impair the receiving water. Some agencies hold the odd belief that it would be inequitable not to require some treatment of every waste, even those that clearly are not deleterious.

The public judges pollution from a purely esthetic point of view. Complaints are made when unsightly conditions are observed, and these must be investigated. It often happens that actual pollution is relatively slight, or the situation may be transient. If the proposal for minimal preliminary reduction in waste load were adopted, agency personnel would gain time for basic investigations. In addition, these initial steps might result in such an improvement in water quality that further steps would be relatively minor. In many instances, however, additional treatment would be needed, but it could be designed on a more sensible basis than would otherwise be the case.

Industrial management generally is not sympathetic to the idea of step-by-step installation of waste treatment. It would much prefer to build one plant that would guarantee immunity from further demands for a long time. Although this attitude is understandable, it is not economically logical, particularly since the cost of waste treatment facilities must be added to the capital structure. Cooperative discussions with regulatory agencies often yield mutually agreeable solutions to this kind of problem.

Conclusions

Problems in the water resources field arise largely from maldistribution of rainfall, both in time and place. There are many competing demands upon available water supplies, some of which are mutually exclusive. Decisions upon optimum beneficial use of water in the broad public interest are difficult to make, because they involve technical, economic, and societal questions. Where there is a will to reach sound conclusions in the national interest, dependable data and cooperative discussions invariably bring them about.

The use of water for final disposal of domestic and industrial wastes has created serious problems. Attempts to reach simple solutions have often relied upon establishment of standards of stream and effluent quality that have been based upon questionable scientific data and doubtful engineering judgment. Arbitrary standards for large areas are not in the public interest, but quality criteria are useful in preserving and improving local water usage. Comprehensive surveys by skilled personnel provide the only satisfactory method for sound control of pollution in the public interest. Surveys are costly and require considerable time, but an initial requirement of minimal reduction of pollution by each contributor to a given locus of pollution may simplify the problem of abatement.

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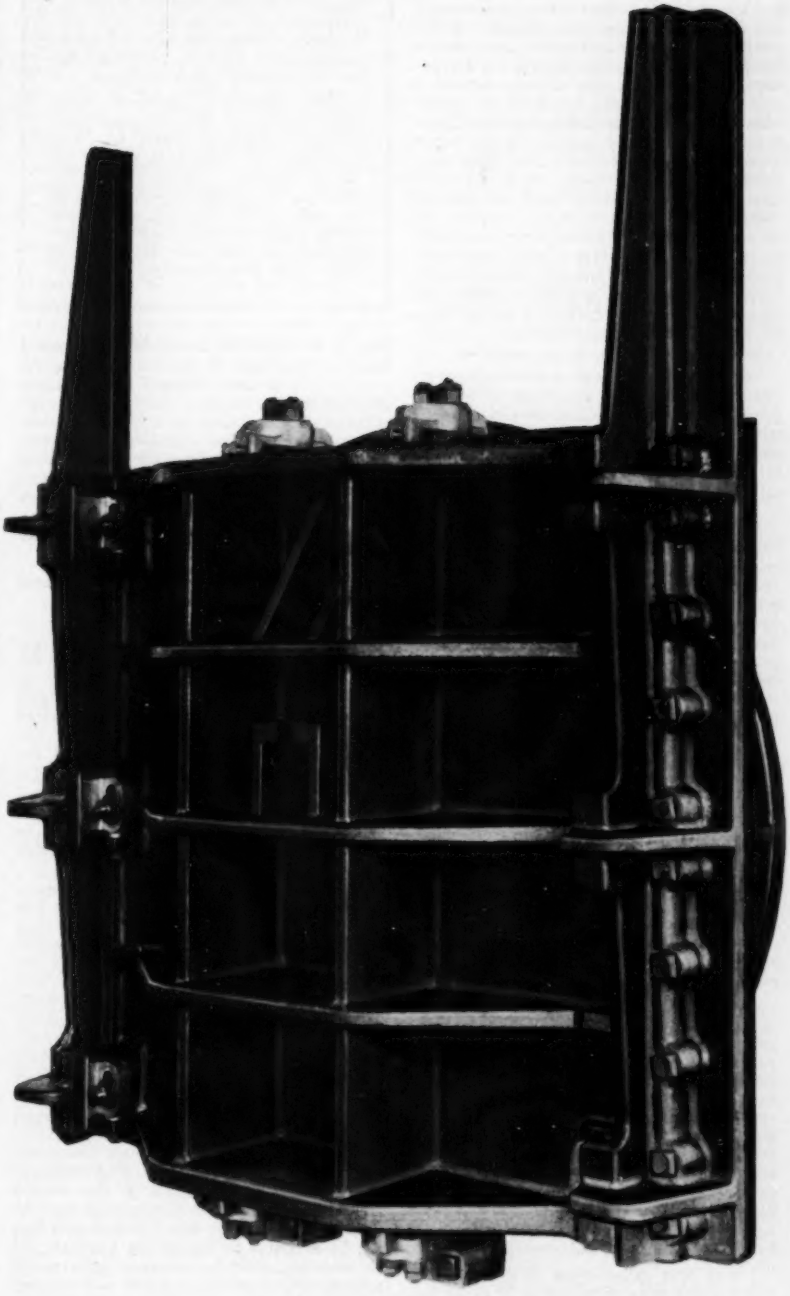

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Financing Sewerage Improvements

By ROBIE L. MITCHELL
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The author of this article, with a background of experience in developing plans for financing sewerage improvements, drew up and later successfully defended the Sewer Revenue Ordinance of the City of Miami before the Florida Supreme Court.

In this important case the favorable decision won by Mr. Mitchell from Florida's Supreme Court not only established the constitutionality of the Sewer Service Charge method of financing sewerage improvements in the state of Florida, but also established a precedent of considerable importance in future cases of like nature in all parts of the country.

ONE of the most pressing problems in many urban communities is the disposal of sewage and industrial wastes. The pollution of our rivers, harbors and inland and coastal waters into which raw sewage and industrial wastes flow directly or are being pumped has not only impaired or destroyed their value for fishing and recreational purposes, but has already become a serious menace to the health of the people and this menace is increasing more and more with the rapid increase in our urban population. Some of our cities pump their water, including the water which is used in their homes, from rivers which are polluted upstream by the raw sewage of another city or by chemicals and wastes from some mill or factory. It would take a lot of persuasion to make me believe that any city or private corporation has the right so to pollute the rivers and harbors which God has given to all the people of this country.

What are we going to do about it?

For one thing, we can require private industry to clean up its own mess by treating it before dumping it into a river, or by running it through a city's sewage treatment plant and paying for the service.

Financing the Big Problem

Our big problem comes in financing the construction of the sewage treatment plant.

In the past the construction of sanitary sewers and sewage disposal systems has been financed for the most part by the issuance of general obligation bonds supported by taxes or by taxes and special assessments. In many cities special assessments for all or a portion of the cost of sanitary sewers have been levied upon the property abutting upon the improvement, whether such property is improved or unimproved. The balance of the cost and the cost of intercepting sewers, force mains, pumping stations and outlets and sewage treatment plants in the cases where they have them, have been borne by the taxpayers at large of the cities. As it is extremely difficult, if not impossible, to sell bonds payable solely from special assessments, the cities would issue their general obligation bonds payable from taxes, the amount of the taxes in each year being reduced by the amount of special assessment collections.

But constitutional limitations and restrictions on the issuance of bonds or the incurring of debt have caused us in recent years to consider the possibility and the feasibility of financing the construction of sewage disposal systems by the issuance of revenue bonds, the interest on which is payable solely from the proceeds of sewer service charges (sometimes referred to as sewer rental) to be imposed on those whose sewage is disposed of or treated by the system.

Legal Questions Involved

I was first called upon to draft legislation for this type of financing 17 years ago. We then had very few court decisions to help us as only a few cities had attempted to impose a charge for their sewers. We have been confronted with these legal questions:

1—What are sewer service charges? Are they related to the taxing power, or are they to be classified as special assessments based on benefits? If the former, must the proposed bonds be authorized at an election or must they be included in computing constitutional or statutory debt limits? If they are to be treated as special assessments, should not provision be made for a public hearing after proper notice? Or are they to be treated merely as charges for services rendered?

2—On what factors should the sewer charges be based?

3—How shall the collection of delinquent charges be enforced?

In 1945 I drafted legislative acts to authorize several cities to construct sanitary sewers and sewage disposal systems, to impose sewer service charges and to finance such construction by the issuance of sewer revenue bonds payable solely from such sewer service charges. For fear that the courts might possibly hold that the sewer service charges to be imposed under these special acts should be treated as special assessments, I provided in the acts for a public hearing on these service charges in substantially the same manner as in the case of special assessments.

I then prepared the ordinance for sewer revenue bonds in two of these cities. The conditions in the two cities are not the same. In one about ⅓ of the area, in which about ½ of the population live, had sewers, through which raw sewage flowed or was pumped into a bay in the city's front yard. These sewers had been paid for by general obligation bonds of the city, payable from taxes on all taxable property in the city and additionally secured by the proceeds of special assessments levied on the property abutting on the sewers. The new project involved the laying of additional sewers in the remaining populated sections of the city and the construction of a sewage disposal plant to treat and dispose of the sewage from the entire city. In setting up the financing program it was felt that it would not be equitable to impose the same charge on property which had already paid special assessments as on the property to be served by the new sewers. So provision was made for companion bond issues, one to cover the cost of the new sewer lines (collection system) and the other to cover the cost of the sewage disposal system, including the *intercepting* sewers, force mains, pumping stations, the treatment plant, etc. The first issue consisted of general obligation bonds payable from unlimited ad valorem taxes and additionally secured by special assessments (for about 60 per cent of the cost) on abutting property. This would place the property owners getting the new sewers on substantially the same basis as those who already had sewers and who had paid special assessments for a part of the cost of their sewers. The second issue consisted of unsecured sewer revenue bonds, payable solely from sewer service charges based on water consumption by the sewer user.

This plan of financing would place some burden on the owners of unimproved property in the new area, special assessments for the new sewer lines in front of such property and a tax to pay a part of the first issue of bonds. The second issue of bonds would be payable from equitable sewer service charges based on extent of use of the sewer in both the old and the new areas.

No One Plan Will Fit Every Case

The consulting engineers suggested that some charge be imposed on all unimproved property in the city in the nature of a "readiness to serve" charge on account of the fact that the construction of the system could be shown of benefit to all property in the city, whether improved or unimproved. But from the decisions of the courts up to that time, including the decisions of the Supreme Court of Pennsylvania in two Philadelphia cases, I feared that any such "readiness to serve" charge would be treated as an exercise of the taxing power, requiring an election on the issuance of the proposed bonds and also the inclusion of such bonds in computing the charter debt limit of the city.

In another city we now propose to include in the sewer revenue financing the cost of the sewer lines in the presently unsewered area and impose an "adjusted" service charge on the people in that area instead of a special assessment. It would appear from two decisions of the Supreme Court of that state that, if the proceeds of special assessments should be pledged to the bonds, it would be necessary to hold an election on the question of issuing the bonds. In another city, where the present sewers are entirely inadequate, many of them must be reconstructed and new sewers as well as a sewage disposal system constructed, the authorizing ordinance which was adopted last month makes a uniform sewer service charge on all users because of the extensive reconstruction required to place the existing sewers in good condition.

I have mentioned these different situations to show that there is *no one plan of financing which will fit every case.* The financing plan for each situation may have to be a tailor-made job and the working out or the setting up of each plan will involve a considerable amount of work and the closest cooperation on the part of the governing authority and its consulting engineers, bankers and lawyers.

Referring now to the three legal questions which have confronted us:

1—What are sewer service charges?

2—On what factors should the sewer service charges be based?

3—How shall the collection of delinquent charges be enforced?

What Are Sewer Service Charges?

In my opinion these questions are closely related and all of them have been convincingly answered by the Supreme Court of Florida in its opinion affirming the decree of the lower court validating a proposed issue of Sewer Revenue Bonds of the City of Miami, reported in 157 Fla. 726, 27 So. (2d) 118, and printed in full in *The Daily Bond Buyer* of August 5, 1946. I feel that this opinion is one of the greatest contributions in the field of municipal finance of any of the court decisions in recent years and that it will be relied on by the courts in other states as the leading decision on the subject.

Prior to preparing the brief in the Miami case, I read every decision on the subject which I could find and a great many articles, some prepared by leading engineers. Analyzing all this and drawing on my very limited knowledge of irrigation law in Montana, where I was engaged in general practice for a few years before getting into the municipal work in the Attorney General's office, I reached the conclusion that, fundamentally, sewer service charges are identical with water rates, that in reality they should be considered to be the second half of the water bill. In paying the water bill we do not pay for the water *itself* as we do for a ton of coal (or a bushel of potatoes) but for its *use*. As stated in my Florida brief,

> "In a modern city a waterworks system would be utterly useless without a system for the disposal of sewage. The service rendered by a waterworks system is only half of the complete service required. Through the waterworks system water which has been purified in accordance with standards prescribed by the proper health authorities is brought to the premises of the consumer for use. Through the sewer system the identical water, carrying the pollution resulting from its use in bathtubs, showers, sinks, washtubs and toilets, is taken from the premises and disposed of in accordance with standards prescribed by the same health authorities. For the service rendered by the waterworks system water rates or charges are imposed. For the service rendered by the sewer system sewer service rates or charges are imposed. The consumer does not pay for the water in either case but for its use, for the service rendered."

I relied to a great extent on recent decisions in New Hampshire, Pennsylvania and Arkansas. The Supreme Court of New Hampshire in Opinion of Justices (1944) 93 N. H. 478, 39 Atl. (2d) 765, had said "sewer rents imposed by the city of Concord are neither taxes nor assessments for a local benefit but, like water rates * * * are charges made for a service rendered." It was contended by the Attorney General that the principle of law which exempts the property of the State from taxation under general statutory provisions also precludes the imposition of a special assessment for improvements upon such property, but it was held that the charges of the city for sewer service are in no sense special assessments.

The City of Philadelphia was authorized by statute to charge and collect "annual rentals for the use of sewers, sewage systems and sewage treatment works," and such charges "shall be apportioned equitably among the properties served by the said sewer, sewage system, or sewage treatment works." In two decisions of the Court it was held that the ordinances passed by the City of Philadelphia did not comply with the statute because they imposed taxes and not charges for the use of the sewers. In the first case (In re Petition of the City of Philadelphia (1940) 340 Pa. 17, 16 Atl. (2d) 32) the ordinance was held invalid because the charge was made applicable not only to properties actually connected with and accommodated by the sewer system but also to vacant lots and properties not connected with the sewer system. In the second case (In re City of Philadelphia (1941) 343 Pa. 47, 21 Atl. (2d) 876) the rate imposed by the ordinance was a combination of two factors: (1) three mills upon each dollar of assessed valuation, and (2) 25 per cent of the water service charge, or water rent. The sewer rental rate based on assessed valuation of properties actually using the sewer system was held invalid as a tax measured by the value of properties served without relation to the use of the sewers.

In the third ordinance, which was sustained in Gericke v. City of Philadelphia (1945) 353 Pa. 60, 44 Atl. (2d) 233, the charge was "based upon the water consumption of the property served as measured by the charges for water supplied (water service) for the then current calendar year."

Only a short time before filing the brief, the Supreme Court of Arkansas in City of Harrison v. Braswell (1946) 209 Ark. 1094, 194 S.W. (2d) 12, sustained an issue of water and sewer revenue bonds of the City, payable solely from revenues of the municipal waterworks and sewer systems, saying:

> "A sanitary sewer system without water would be a total loss, and a water system without a sanitary sewer system would be impractical, if not entirely useless. So each complements or supplements the other."

In its decision in the Miami case the Florida Supreme Court held that the imposition of fees for the use of the sewage disposal system is not an exercise of the taxing power or the levy of a special assessment, saying:

> "A sewer system is complementary to a water system. A sewer system would be of no value without a water system and a water system would be entirely incomplete without a sewer system. So the principles of law which would apply to one system must likewise apply to the other."

Basis of Charges

Referring to the second question, the sewer service charges in the Miami ordinance were a certain percentage of the water bill, which in turn is based upon the quantity of water consumed as determined by meter measurement. This method appears to be the most equitable and was sustained by the Florida Supreme Court.

Collection of Delinquent Charges

As authorized by a provision we incorporated in the special legislative act, the Miami ordinance provided that the amount of the sewer service charges shall be actually included in the water bill, but each bill showing separately the amount of the sewer service charges and the amount of the bill for water, and that if the sewer service charges are not paid within thirty days from the rendition of the bill, the City shall discontinue furnishing water to the premises and shall disconnect the same from the waterworks system of the City.

In approving this method for the collection of delinquent sewer service charges, the Florida Supreme Court said:

> "Question Three is closely related to Question Two because it challenges the method provided for the enforcement of the charges for the use of the sewage disposal system * * *.
>
> "It is uniformly held that the City may cut off the water being furnished by the City to a consumer when such consumer fails to pay the water bill. * * *
>
> "It appears to us that if no constitutional rights of the owner or occupant of premises are violated by shutting off the water for non-payment of the water bill, no such right will be violated by shutting off the water for non-payment of the bill for use of the sewage disposal system, the two services being so interlocked that neither can be effective without the other."

In other words it becomes a case of "New and Used Water" as one water and sewage works manager has so aptly put it.

Forcing Connections with Sewer System

In cases where the premises of a substantial percentage of the population are using septic tanks and are not connected with the sewer system of the City, we have another problem. Is it lawful to include in the ordinance authorizing sewer revenue bonds a provision requiring the owners of such premises to connect with the sewer system and cease using their septic tanks?

If the construction of the sewage disposal system is to be financed by revenue bonds, payable solely from sewer service charges, a requirement to connect with the sewer system or else pay the charge in any event may be important. But if the construction is to be financed by general obligation bonds or if the statute authorizes, and the constitution of the state permits, the imposition of a readiness to serve charge on such premises, the financing may not be seriously affected.

In sustaining this provision in the Miami ordinance the Florida Supreme Court said:

> "The reasonableness or unreasonableness of the provisions of the section complained of must depend largely, and may depend entirely, upon the character of the terrain of the area affected * * *.
>
> "What may be considered an unreasonable requirement to be applied in a village located on the red clay hills of Leon County might be a regulation vitally necessary for the protection of the public health and welfare of the inhabitants of a city, the larger portion of the terrain of which is not more than 10 or 12 feet above sea level and a less distance above the average water table.
>
> "Private rights must always be subordinated to public rights and the public health is as sacred as any public rights can be. * * *"

Ownership of Water System Important

We have another problem in cases where the ownership and operation of the water system and the sewer system are not the same. Fortunately over 90 per cent of the urban population in this country is served by publicly owned water plants. But where a city or a substantial portion thereof is served by a water plant that is owned by a private corporation, can satisfactory arrangements be made with such corporation for computing and collecting the sewer service charges? Will it shut off the water for non-payment of such charges?

Where the pollution is caused by the sewage and wastes from several cities, towns and villages, we have still another problem. In some cities where I have been

working it is expected that the City will construct and operate the sewage disposal system and finance such construction by sewer revenue bonds of the City and then enter into contracts with the adjoining communities for treating their sewage. In some cases where there are several cities and towns, each owning its own sewer system and each being served by a separate water system, it will probably be necessary to enact legislation setting up a sanitary district or a sewer authority covering the entire territory. The preparation of such legislation will not be an easy task and working out the financing plan on an equitable base will be even more difficult if there are any privately owned water plants within the territory.

The Portland Water District as an Example

You may be anxious to have me make some suggestions in connection with your own situations, particularly here in Portland. But, as I have said, the financing plan for each situation must be a tailor-made job. The Portland Water District is a quasi-municipal corporation created by a special act of the Maine Legislature. The District supplies water to the City of Portland and several adjoining cities and towns. I understand that the City of Portland has its own system of sanitary sewers through which sewage flows untreated into the bays and waters surrounding the City, and that the pollution of these waters is now or may soon become a menace to the health of the inhabitants of the City. If this is true, it appears to me that it would be advisable for the City to have a thorough survey made of the situation, in the first instance by its own engineering, finance and legal departments and then, at the proper time, employ outstanding consultants, particularly consulting engineers who have specialized in this particular line, to cooperate in the preparation of a comprehensive plan for construction of sewage disposal works and the financing of such construction. In the preparation of such plan, consideration must be given to many matters, such as:

1—The type of treatment best suited to the situation, the design and location of the sewage treatment works, intercepting sewers, force mains, pumping stations, and other equipment, the cost of construction and the annual expenses of operation and maintenance.

2—The necessity from a health standpoint of constructing sanitary sewers in any unsewered areas.

3—The extent and the condition of the sewer facilities in the adjoining cities and towns and to what extent the sewage from these facilities contributes to the pollution to be abated.

4—If the construction of a sewage disposal system shall appear to be necessary, by what public instrumentality shall it be constructed and operated, and shall such construction be financed by general obligation bonds or revenue bonds? If all or substantially all of the area to be served is within the limits of the City of Portland, perhaps the City is the proper instrumentality. If so, in determining the type of bonds to be issued, consideration should be given to the margin between the present debt of the City and its legal debt limit and the necessity of preserving that margin for other public improvements.

But regardless of the ability or willingness of the City to issue its full faith and credit bonds, I would urge that careful consideration be given to the matter of issuing sewer revenue bonds, payable from sewer service charges to be imposed only upon those who actually use the system. If this plan should be adopted, however, who will collect the bills? The Portland Water District owns the water plant. Would it like to be a collection agency for the City? If so, how will it enforce collection, and will it be willing to shut off its own water for non-payment of the City's sewer service charges?

Perhaps the Water District is the proper instrumentality. It has done an excellent job in bringing pure water to the premises of those who use it. This, however, is only the first half of a complete service. The other half is the disposal of that water after it has been polluted by the user.

Reasonableness of Charges

Financing the construction of sewage disposal systems by the issuance of sewer revenue bonds, payable from sewer service charges added to the water bill, is comparatively new. There have been some objections to this type of financing on the grounds that the improvement is of general benefit to the community and should be paid for by a general ad valorem tax. I have no legal objection to this plan if the financial structure of the city or town will stand it. But it seems to me that real estate is carrying about all the load that it should at the present time. It is taxed for schools, police and fire protection and many other essential functions of government, both state and local, that cannot be financed in any other way. But in the case of many of our public facilities and utilities I believe that it is more equitable to require the users to pay for them.

What Will the Sewer Service Charges Amount To?

In an ordinance which I have recently prepared authorizing Water and Sewer Revenue Bonds to finance improvements of the City's waterworks system and also additional sanitary sewers and new sewage treatment facilities, the initial sewer service charges to pay the principal and interest of that amount of the bonds which are to be issued for the sewer improvements and to maintain and operate the complete sewer system after the construction of the improvements, will be 65 per cent of the water bill, after making proper adjustment for water not entering the sewer system, such as water used in the sprinkling of lawns, for air conditioning, steam production, etc. In another City for which I am working the sewer service charges will probably be as much as 100 per cent of the water bill.

Are such charges reasonable? Let us consider the service which is being rendered by a waterworks system and the service which will be rendered when the second half of the job is done.

The charge of the Portland Water District for delivering 1,500 cubic feet of pure water to the consumer is $2.50. A cubic foot of water weighs 62.3 pounds, 1,500 cubic feet weigh 93,450 pounds, almost 47 tons. In other words, the water user pays less than 6c a ton for water delivered into his home. What do you have to pay up here for a ton of coal or a ton of fuel oil delivered to your home? For the price of a pack of cigarettes you get three tons of pure water. On the basis of the sewer service charges I have just mentioned, you would pay from 4 to 6 cents a ton for taking away and cleaning up the water after you have fouled it.

It appears to me that such sewer service charges should not be considered unreasonable to the people in any community, particularly if they are fully advised through the press and public meetings how serious a menace to their health the present situation is and how small will be their individual contributions to remove this menace.

The people in a community never object to improving their water system in order to effect cheaper fire insurance. Why not provide some health insurance in addition?

For another valuable article on sewage works financing which discusses "Fundamental Considerations in Financing Sewage Works," includes a Model Sewer Revenue Ordinance, and presents methods of Billing and Collection of Sewer Service Charges, see pages R, 111-115 Reference & Data Issue of April 1951. Also see Report of Joint Committee on Rates and Rate Structures for Water and Sewage Works representing legal, financing, management and engineering interests in establishing charges for water and sewage service. Copies are available from the Ohio State Law Journal, Ohio State University, Columbus, Ohio, at seventy-five cents each.

Most recent report on sewage works financing is "Sewage Service Charges in Cities Over 5,000 Population", Special Report No. 18, November 1953, published by the Amer. Public Works Assn., 1313 East 60th St., Chicago 37, Ill., at $2.00 per copy. It presents the most up-to-date information currently available on the use of sewage service charges in the U.S. These data should be of particular value to municipalities contemplating the use of sewage service charges, as both sewage disposal service and sewer service charges are discussed.

Trenching Practice

By RICHARD BENNETT, C.E.
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PART I—EARTH TRENCHING

A TRENCH is an excavation having vertical sides and considerable depth in comparison to its width. For purposes of this article it will be considered as being less than 6 ft. in width and not more than 30 ft. in depth, which permits excavation by modern trenching machinery.

Trenches are dug for all kinds of pipe lines, including water, sewer, gas, oil, drains, conduits, etc. The large amounts of trench excavation made necessary by the installation of pipe lines for the various uses has led to many improvements in this practice.

Many of the early forms of trenching machinery such as the traveling derrick, the trestle cable excavator, the tower cableway, the trestle-track excavator, etc., have all given way to the modern ladder type and wheel type trenchers.

Modern trenching machinery was first perfected about 1910. It gives low cost excavation plus fast rate of progress. It is a part of almost every pipe line construction job. Except for very small jobs, hand trenching labor is generally found inefficient and uneconomical. If the ground is free of large, heavy obstructions, and not too hard, the modern trencher is very efficient.

Type of Trencher Most Suitable

The type of trencher to use will depend upon local conditions. If the trench dimensions are small, and much maneuvering is required because of restricted conditions, then some of the smaller trenchers will prove best.

Many consider the wheel type trencher is a harder digger than the ladder type. In hard and tough clays, for medium depths and widths, this type is most efficient. These designs are generally limited in maximum widths and depths of trenches excavated, the maximum being about 3½ ft. width and 8½ ft. depths.

Where trenches of greater width and depths are involved, the ladder type must be used. If stones, not too large, are encountered occasionally, the ladder type is more efficient to loosen them, being partly due to the vibration of the boom, whereas the steadiness of the wheel type excavator would not accomplish the same result.

On most of the ladder type trenchers the boom may be telescoped so that the depth of the trench may be increased or decreased with little difficulty.

In any case, if the digging is difficult, then the high-powered types must be used.

Some trenchers are designed for use in cramped quarters, such as narrow alleys, parkways, close to curbs, buildings or other obstructions, etc. With some the boom may be shifted to one side so that the trench may be cut close to side obstructions.

Maximum service is desired in a trencher. They are subject to hard, grueling service, and their design should sacrifice nothing which would affect durability.

With modern trenchers the spoil bank may be located on either side of the machine, or loaded into trucks or on conveyor as desired. The spoil conveyor will place the spoil bank back from the trench sufficient distance to give a good clean shoulder on which the workmen are not hindered in laying the pipe. When extensions are added to the spoil conveyor the desired height of the spoil bank may be secured to care for the earth from deep trenches.

Parson's "Trenchliner"—250—With Offset Boom
(The boom, now operating at center, may be shifted to any desired position across entire width of chute. Thus the trencher may operate on road shoulders, in narrow alleys, close to curb lines, buildings, trees, etc., without harm or difficulty. The spoil bank can be on either or both sides.)

Trenching Methods

If the trench is deeper than the trencher will excavate, there are two methods which can be used to gain extra depth without undue expense. (a) Excavate with scrapers sufficient depth from the surface and the full width of the trencher so that the trencher can excavate to desired grade line. Several feet of added trench depth can be secured in this manner. The spoil conveyor can be lengthened so that the earth may be removed either to spoil bank or to trucks as desired. (b) Under most conditions it is possible to remove about two feet of earth below the trencher cut, and throw the spoil back onto pipe already laid in place. Using two workmen, one with air spade and the other to shovel, this work can be done at a rather rapid rate of progress. Using the combination of these two methods, several added feet of depth can be economically secured.

Estimating Practices in Trenching

The trenching contractor is beset with many difficulties and uncertainties, therefore estimates must allow for many unpredictable contingencies. It is impossible to know exactly just what will be encountered until the trench has been excavated. The trenching estimator must judge many factors to the best of his ability.

A visual survey of many jobs will enable the estimator to determine, with reasonable accuracy, whether the job will present many interruptions; on the other hand, too much dependence must not be placed on such surveys in built-up areas. Questions concerning wells, excavations, etc., made previously in the area will reveal many facts. Many pipe line contractors have suffered great losses by not familiarizing themselves with the underground conditions to be encountered.

Much experience is required to properly estimate different conditions and proper methods of pipe line work. Some estimators estimate the job as close as existing data will permit, then add a percentage for uncertainties—a method but little better than a shrewd guess. The estimator who can accurately determine costs on two or more methods for the same job, is worthy of his hire.

In pipe line construction, the cost of trenching is usually the major item, depending upon digging conditions. The kind of earth involved makes much difference in the unit costs. These costs increase according to the types of earth, somewhat as follows: light earths and sand; loam and light clays; dry, hard loams and tough clays; dense and tough adobes; coarse gravels, cemented gravels; hard caliche; and disintegrated granites. All these materials produce different unit costs.

Labor Costs

Labor costs are not materially increased with the light earths, sand loams and clays, but such costs are increased with the tough, dense clays, adobes, varying with the amount of pipe bedding required. Mud, especially if it is sticky, will greatly increase costs. Unforeseen conditions, such as solid rock, boulders, water, caving soil and even quicksand conditions will greatly increase costs.

The estimate must include: excavation, sheeting, backfilling, equipment rental; moving to and from job; and if water is likely to be encountered, then an allowance must be included for water pumping and disposal.

The labor expense will include foremen; machine runners, helpers or swampers; pipe layers; laborers; timbermen; backfillers; as well as extra roustabouts. The cost of superintendence and supervision can generally be estimated as a percentage of the payroll.

Fixed Costs

Fuel, supplies, and equipment repairs will generally be a large item with most jobs. To determine the fixed costs per day, the contractor must make assumptions which are later adjusted in the light of actual facts. Some depreciate trencher equipment at 60 months' total life; however, many individual pieces of equipment have lasted both much longer and even shorter time than this. Some authorities estimate yearly costs of this equipment somewhat as follows: depreciation, 20 per cent; repairs, 18 per cent; interest, insurance and taxes, 7 per cent; miscellaneous, 4 per cent. Total fixed charges per year—approximately 50 per cent of original cost of trencher. The total fixed costs per year divided by the units of work performed gives the actual job cost for using that particular machine.

About 4 per cent of the payroll should be charged for small tools. Miscellaneous materials required for the work as the job progresses will generally average about 1 per cent of the payroll. Small jobs, unless the management is excellent, will produce high unit costs.

Daily Cost Analysis Important

The cost analysis of trenching for every job should show the width and depth of trench; type of soil; the total footage excavated; the number of cubic yards excavated; the total overhead and operating expense of the trencher; the daily expense of trenching; the footage expense of trenching; and the cubic yard expense of trenching.

The unit costs should separate excavation; pipe laying; back-filling; cleaning up, moving to and from job; and overhead. The analysis should show minimum, average, and maximum day's work and reasons, together with average of all items for the entire job. These data, kept up daily, will show and determine all leaks and losses on the job.

Cleveland Trencher

(Cutting through a soft-rock formation in Texas called the Austin Chalk. Note the clean cut made. Trenchers of the ladder type are also good in shale, consolidated gravel and all but hard solid rock.)

PART II—ROCK TRENCHING

What was said in Part I on trench excavation in dirt may also be almost wholly applied to trenching in rock. Rock trenching is a time and labor consuming proposition. The fact that it is not often encountered probably accounts for the great variation of methods adopted on different jobs. The technical literature contains almost nothing on this subject. Ask the manufacturer's blasting experts and they merely say, "I will get you something on that." (Period!)

System Lacking in Rock Trenching

Most rock trenching jobs have little or no system. Costs are high, progress is slow, and those in charge make little or no endeavor to find the most economical method for that job.

In rock trenching the quality and quantity of the rock will generally determine the proper method of excavation. For economical work it is necessary to give much thought and attention to the job methods.

The types of rock encountered may vary from hardpan to dense, tough granites; each will require a different method of drilling and shooting.

There does not seem to be any current standard practice in the spacing of drill holes. Each foreman seems to have his own pet ideas—very few of which would stand much investigation from an efficiency viewpoint.

Proper spacing of drill holes will depend on the nature of the rock and local conditions, but cut and try methods must be utilized to ascertain the most economical method.

Drilling Requirements

The number of feet of hole to be drilled per cubic yard of rock to be excavated will vary greatly with different jobs, conditions, and job methods. Spacing will depend upon nature of the rock and width of trench. Properly determining this factor requires much ability on the part of the job manager. This determines ultimate unit costs.

For average rock the following table may be used to determine trial hole spacing:

Width of trench (feet)	Number of rows of holes
3	2
6	3
9	4
12	5
15	6

The outside row of holes should be in line with the trench wall. It is seldom that cross-trench hole spacing greater than 3 ft. can be successfully used. At times the longitudinal spacing can be increased to 4 ft. or even slightly more, especially in the wider and deep trenches. The greatest economy is secured in using maximum depth for holes.

The necessity for protecting adjacent structures, whether underground utilities or nearby buildings, will influence drill hole spacing.

If power excavation equipment is to be used, it is seldom possible to blast a single line of holes down the center of the trench. With but one line of holes too much projecting rock remains to be loosened by prying and barring by hand methods, thus greatly increasing costs.

Care must be taken to keep the drill holes clean until they are loaded. If the hole contains debris or water, this is best removed with compressed air. Ice frozen holes may be cleaned out with steam; this also warms the hole sufficiently so that the explosive will not freeze. A wooden plug should be driven into each hole as soon as the drilling is completed, to keep out extraneous materials; this plug also aids in finding the hole later.

A Well Braced Trench

Proper Quantity of Explosives

Determining the proper amount of explosive to use will require trial and error determination. Experience and good judgment helps very much. In any case carefully kept notes and records are of immense value.

In trench blasting only one narrow face is open, therefore more explosive is required than for open surface blasting. The amount and strength of dynamite to properly use will depend upon all the factors mentioned for spacing of drill holes. The amount of explosive required per cubic yard of rock removed will depend upon the nature and type of rock and the method adopted. The amount of explosive per hole may be limited by the necessity for controlling flying rock, excessive noise or vibrations, and danger to nearby underground utilities or adjacent structures of any nature.

Dynamite is generally used for trench blasting; the grade used depending upon the type and quality of rock encountered. The quantity required may range from about ¼ lb. per cubic yard in soft sandstone to 3 lbs. or more in the hard, dense rocks.

Different rocks and formations do not blast alike to meet given conditions. The specifications for the work may limit the amount and kind of blasting that may be done on the job. Oftentimes blasting is restricted due to local conditions.

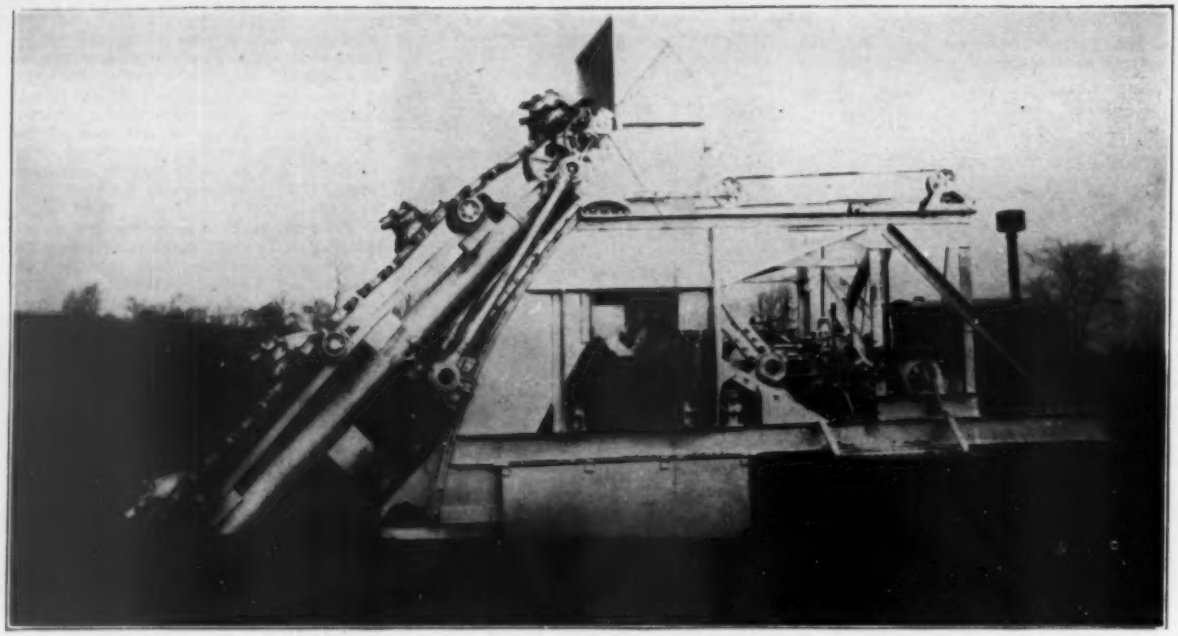
Selection of Proper Explosives

The type of explosive to use will depend upon the type and quality of the rock; local conditions; etc. The greatest waste in explosives is in using a grade or type not suited to the job at hand. A low grade of explosive should be used for soft, weathered rock; to use high grade explosive here, is to waste much of the explosive energy. High power explosives lack propelling power when used in blasting soft rocks.

Too many use only one type and grade of explosive — generally 40 per cent strength. This is poor economy. Some arbitrarily use 60 per cent to secure sufficient shattering and also to loosen rock bound in place. If the rock is not shattered sufficiently, then a higher grade should be used. If the rock is shattered too much, then a lower grade should be adopted for the job.

A high power explosive should be used for hard, firm rock. If the bottom of the hole does not shoot properly, then it may

Koehring's Trench-Hoe
(A rugged piece of equipment, useful where the going is tough—boulders, hard shale, blasted rocks, etc.)



Buckeye Model 120 Trencher

(Buckeye also makes a wheel-type trencher satisfactory for water-line trenching, requiring less depth and permissive of faster travel where the going is easy.)

be best to use a high grade explosive at this point. In such cases place the firing charge at the top of explosives so that the explosive gases will tend to concentrate at the bottom of the hole, thus producing greater rupture at that point.

Sufficient shattering must be secured to permit easy removal of the rock from the trench. It is not possible to use ladder type of trenchers for rock trenching, except in the very soft formations. A pull shovel or trench-hoe may often be used to good advantage in rock trenching.

Rock Excavating Equipment

In shallow trenches the rock may be removed by hand. For hand excavation the rock must be broken into small pieces by either blasting or subsequent breakage.

For deep rock trenches the use of drag line or pull-shovel is most economical. These types of equipment are well suited for this work. The rock must be thoroughly broken up, and the wall sufficiently straight not to hang up the shovel. Rocks too large to be removed by the bucket should be hoisted from the trench with chains.

Limestone is easily drilled. It is occasionally found in horizontal layers, and may be blasted like building stone. In seamy formations, the holes must be closely spaced to retain the force of the explosion. Seamy rocks permit the explosive gases to escape and the full effect is not retained in shattering. Seamy rocks, lying at an angle cause the drills to stick and straight walls may be secured in blasting bind in the hole. Relatively smooth and soft sedimentary rocks.

Granite and igneous rocks break out in rough, irregular walls. If the holes are thoroughly and tightly tamped, then the explosive will give most effective results, due to confining the explosive gases. Trap and quartzite are generally difficult to drill.

Two factors should be kept in mind at all times in rock trench excavation: the number of feet of hole drilled per cubic yard of neat excavation; and the amount and strength of dynamite used per cubic yard of excavation; both of which sum up to: cost of breaking up the rock for satisfactory removal.

LAND MEASURE

A Quarter Section of 160 Acres Divided to Show Relationship of Rods, Chains and Feet

A rod is 16½ feet.

A chain is 66 feet or 4 rods.

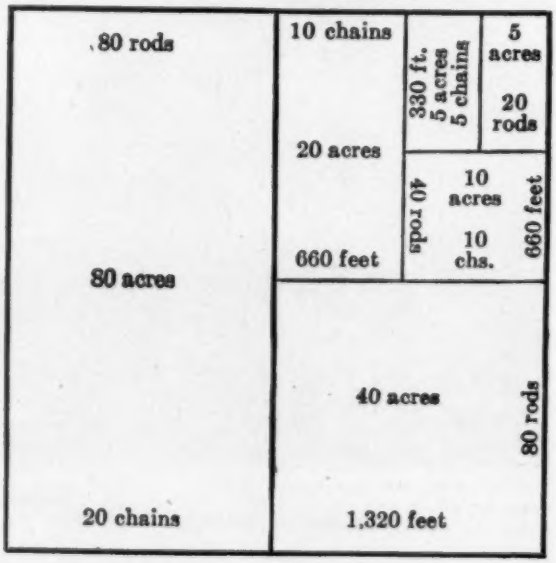
A mile is 320 rods, 80 chains or 5,280 ft.

A square rod is 272¼ square feet.

An acre contains 43,560 square feet.

An acre contains 160 square rods.

An acre is about 208¾ feet square.



A Preventive Sewer Maintenance Program

By WILLIAM M. COLONY
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JUST when you're getting to sleep, the night foreman calls to inform you that Mr. Jones' basement is flooded with sewage; furniture, trunks, and tools are ruined and he's ready to sue! Just when you enter a busy conference, the radio man reports a surcharged line spilling sewage into the local park—and the park officials want immediate action. Just when you finally settle down to finishing last month's reports—always when you're busiest—emergency maintenance calls interfere with your tasks, incite the public to hasty condemnation of your organization, and necessitate the expenditure of more men, more time, and more money.

Isn't it possible, somehow, to anticipate and prevent at least some of these emergency calls? With that question as a starting point, the following considers the suggested components of a plan which the Washington Suburban Sanitary Commission is now undertaking; a plan which finds the trouble before it becomes real trouble; a plan which, when fully developed, saves energy, talent, and money for more constructive work. This plan is generally known as preventive sewer maintenance.

Three Basic Phases

Preventive sewer maintenance is a planned program of inspection, servicing and repair of the sewer system. The need for such a program is obvious when the problems to be dealt with are examined. The causes behind emergency maintenance are almost as varied as they are numerous. The largest group may be listed under main-line stoppages—stoppages due to roots, sand or gravel, grease, and other material which has blocked the normal flow of a sewer. Besides relieving main-line stoppages, emergency maintenance is necessary when a surcharge of the sewer floods surrounding basements. This condition of surcharge is caused by the entrance of rain water and ground water, or by insufficient capacity of the sewer during the periods of peak flow. Preventing these problems becomes the task of a program of preventive maintenance.

Mr. Colony's article is reprinted from J.F.S. & I.W.A., Vol. 25, p. 490, with permission of the Association.

As already indicated, the three basic phases of the program are inspection, servicing, and repair. Those phases dealing with inspection and servicing are the most important, and, when treated as such, will greatly reduce the repair phase. Without question, this is the end reward of a preventive program. If this reward (reducing of repair work) is to be realized, then much time and thought must be given to planning the inspection and servicing aspects of the program.

Listing of Problems

The first objective of the maintenance engineer is to make a listing of the specific problems of his system. Such a listing can be made only after a thorough study of all available past records dealing with the maintenance of the sewer system. These records, if complete, will enable the engineer to assemble data concerning the location, type of complaint, and maintenance required to correct the trouble, as well as the frequency of occurrence. A program of periodic inspection and maintenance of the entire system should be designed to meet the conditions disclosed by this study. If past records are not available, now is the time to start assembling a complete file on every emergency sewer call received. The information contained in accurate and complete records forms the major building block for any successful preventive maintenance program.

Inspection Phase

Inspection, which is a critical examination, is the method employed by the maintenance section to determine the need for servicing sewers. A routine inspection program applied to the entire sewer system must be established to locate potential stoppages and areas subject to surcharge. An inspection of every sewer in the system would be made at least every five years. In some cases, however, records of frequent emergency maintenance may show a necessity of inspection as often as every three to six months.

In many instances, the inspection and servicing phases of the program may be carried out jointly. A good example of this is found in blocked manhole channels. When the inspection crew discovers trouble in a manhole, it can easily correct the condition without losing valuable time in delegating the responsibility to a servicing crew. The servicing crew may likewise assume some of the responsibility for inspection. When doing a routine maintenance job, inspection sould be made of the main-line sewer adjacent to the portion being serviced. The interrelationship of these crews is both logical and practical.

Planning

When planning the inspection phase, the sewer system should be divided into drainage areas. If this is done, the problem of keeping clear, accurate records of inspection will be simplified. The information to be recorded should include the date, the condition of the line, including any leaks or crushed areas, and the maintenance required. It will be advantageous to record the number of manholes inspected, cleaned, and located, and the number which will require adjustment or repair, such as raising and waterproofing. The records for such inspection are the basis for planning the work of the servicing or maintenance crew.

Inspection Crew

An effective inspection crew is composed of a foreman and three laborers and allows for one man on the street at each manhole during inspection.

Records

The foreman on the job should be supplied with two report forms; a daily record sheet on which to note all necessary information pertaining to the inspection, and a maintenance workorder sheet on which to detail the servicing which the line may need. In addition, the foreman will need a detailed map of the sewer lines in the area to be inspected, and, before leaving the job, should mark the stretches on this map to substantiate visibly the written records. This combination of daily records and maps clearly sets forth the progress of the inspection crew and provides cross-identification of the trouble spot when an emergency call is received from that area.

Locating Stoppages

When the inspection crew searches for possible main-line stoppages, it is easy to make visual inspection of

the line by using powerful flashlights and mirrors. Although a beam of light does not always penetrate a long stretch of sewer strongly enough to disclose stoppages to the naked eye, it will reflect on a mirror held at the end of the stretch if the line is clear. Lack of such reflection reveals the presence of foreign matter in the line.

Reduction of Root Stoppages

A job which the inspection crew can handle, and which has reportedly produced excellent results, is that of treating the sewer lines with copper sulfate to discourage root growth. About 2 lb. of this chemical in crystal form, put into all terminal stretches during regular inspection, should reduce the occurrence of root growth and help to relieve a troublesome condition.

Surcharge

Another problem dealt with under the inspection phase of the preventive maintenance program is that of surcharge of the main sewers. It has been pointed out that surcharge may be due to insufficient capacity of the sewer or to the entrance of rain or surface water into the sanitary sewer. Inspection can be planned to locate and forestall the occurrence of this condition.

To anticipate and prevent surcharge caused by insufficient capacity, a program of annual flow tests of the trunk sewers in the system should be organized. Again, the sewer system can be approached on the basis of drainage areas. The trunk line within each area should be tested to determine the maximum rate of flow at the important points of sewage concentration. The rate of flow in the trunk sewer just below and just above the discharge of sewage from a large tributary area will serve as a guide for planning a relief sewer line before the need arises. Records of these flow tests may be kept on a map of the drainage area and should include, as well, the design capacity of the stretches of trunk sewer under study.

Surcharge due to the entrance of ground water or rain water may arise from several different conditions, both accidental and deliberate. The most frequent of these conditions, and, consequently, the source of many emergency calls, are open manholes in low areas, the manhole frames and covers pushed off during grading and paving operations. Routine inspection of new building developments will disclose such potential cases of surcharged lines. This inspection can be most effective during rainy periods, when it is possible to trace muddy water through the sewer lines to its source.

Where surcharge is not due to these indirect sources of rain water or ground water, it may be necessary to survey the foundation drains, downspouts, and large areaways or driveways in an area to determine the number connected to the sanitary sewer system. These surface-water connections, by introducing rain water and ground water into the sanitary sewer, may surcharge it. When the inspector with his crew locates an illegal connection, proper steps should be taken to have it eliminated. The time, effort, planning, and expense involved in such a survey are far less than that necessary to construct a relief sewer.

Constant alertness for line stoppages and for causes of surcharge are but a part of the many jobs composing routine inspection under a preventive sewer maintenance program. The problems existing in each community determine the additional phases of the inspection program. It should be obvious that getting to the source of trouble before it can become a midnight headache, by routine conscientious inspection, can greatly reduce emergency maintenance and will result in lower operating costs and more effective operation of the sewer system.

Maintenance Phase

The establishment of planned maintenance, based on past records and on inspection reports, is the second phase of any preventive maintenance program. Planned maintenance, the logical follow-up of planned inspection, can insure economy and a more efficiently operating system.

The maintenance of a sewer system should include flushing and dragging of the sewer lines, the relief of stoppages, and the repair of appurtenances. Such servicing should also be a systematic program, utilizing the inspection reports, and carried out by maintenance crews, which will vary in size and number with the amount of work to be done. When the inspection crews report line stoppages, the maintenance crews relieve those stoppages by rodding and dragging the line. Necessary work on manholes, in the way of raising, repairing or waterproofing as reported by the inspection crews should be done by the maintenance crews. When the maintenance crews have dragged roots from a clogged line, they should be instructed to treat the line with copper sulfate crystals as a precaution against further root growth in the sewer. The servicing program should also include the coverage of the recurring trouble spots throughout the sewer system.

Repair Phase

The third phase of a preventive maintenance program is repair. The repair crews should be used to relay portions of sewers which are crushed or otherwise damaged, and to replace damaged house connections. The scheduling of the work of these crews can be based on the reports of the inspection and maintenance crews and on emergency calls. In many cases, the maintenance and repair crews will be one and the same, depending upon the amount of work to be done and the number of men to do it. As has already been pointed out, if a program of preventive maintenance is carried out the repair work on the sewer system will greatly decrease as the inspection and servicing phases become more effective.

When planning a program of preventive maintenance, the interrelationship of each of the three phases is an important factor to be considered. The division of one phase from the other depends, of course, upon the situations which occur in each system and locality. It may be well to remember, however, that "a chain is only as strong as its weakest link," and although some amount of division is necessary, coordination of effort will strengthen the whole program.

Commission Program

The preventive sewer maintenance program of the Washington Suburban Sanitary Commission was started in April, 1951, when a systematic inspection of the sewer system was undertaken.

The inspection program is being carried out by one crew consisting of a foreman and three laborers. Their inspection operations follow the general outline previously suggested. Between April 1 and December 31, 1951, 118.83 mi. of sewer lines and 5,535 manholes were inspected, 173 manholes were cleaned, and 5.52 mi. of sewer lines required servicing by maintenance crews. The progress of this inspection crew has been retarded because, in years past, many manholes in this drainage area were covered over and had to be relocated and dug out before the procedure could continue.

In an effort to prevent the occurrence of root stoppages, the inspection crew has been dosing all terminal stretches of the main lines

inspected with approximately 2 lb. of copper sulfate crystals. The period during which this treatment has been used is not yet sufficient to give conclusive evidence of its effectiveness when employed as part of a long-range plan. Re-inspection of a few key stretches where root growth was evident before treatment has disclosed that the dosing was about 50 per cent effective. Further checks will be necessary before a definite conclusion as to its efficiency can be reached. The maintenance crews, as well as the inspection crew, are supplied with copper sulfate crystals and after dragging roots from a line are instructed to apply the copper sulfate treatment to discourage further root growth.

During the past year, it was necessary for the Sanitary Commsision to make a survey of a large area where surcharge consistently occurred during rainy periods. The drainage area was subjected to careful study, which included flow tests on all main-line sewers and a house-to-house check for illegal connections of drain tiles, downspouts, oversize areaways, and driveways. It was determined that the surcharge in this case was due to a combination of insufficient capacity in a portion of the main-line sewer and the entrance of ground water and rain water through regulation-size areaway drains.

In addition, 1951 saw the limited beginning of a program of annual flow tests of all trunk sewers in the sewer system. One trunk sewer was completely surveyed. In addition, the rate of flow was measured at one point on all other trunk sewers and interceptor sewers throughout the system. In order to continue and expand the program this year, plans are nearing completion for making flow tests on each trunk sewer at points of confluence with sewer lines from large contributing areas.

As for the Commission's servicing and repair organizations, a careful examination has revealed the need for improving both techniques and equipment. Only a better program of routine maintenance can prevent recurring emergency calls. With ample past records in the files to aid in the planning of such a program, it is hoped that the routine maintenance procedure will be successfully established in the near future. In conjunction with this study, an attempt is being made to evaluate the effectiveness of the present sewer cleaning equipment as compared with other equipment which may be available. Specific recommendations based on this phase of the study will be made in an attempt to improve both methods and equipment.

This program is considered as a beginning in the right direction and it is hoped to learn as it progresses. An open-minded attitude toward new ideas, and a genuine desire to improve services wherever possible, will lead eventually, it is felt, to a time when the causes of trouble can be anticipated before an emergency arises. That, in substance, will be effective preventive sewer maintenance.

Terminology in Pumping

From Hydraulic Data*

Static Head is the vertical distance in feet between the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head, is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

*From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

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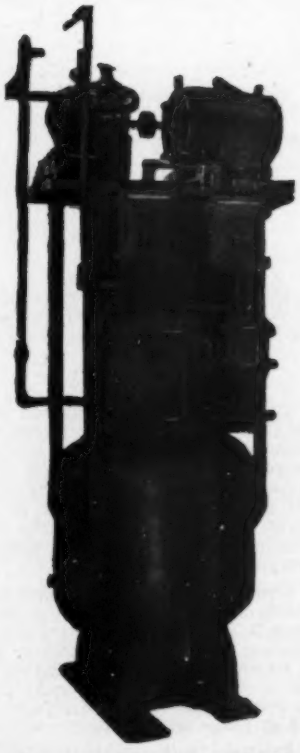

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Design of Sewage Pumping Plants

A practical method of estimating present and future capacity needs

By RAYMOND G. MARTIN
Asst. Civil Engr., Bur. of Engineering, City of Los Angeles, Calif.

ONE might say that the design of a sewage pumping plant is only a series of estimates. Actually it is a pyramid of estimates. Everything from the area to be drained to the final construction is based on calculated estimates.

Unfortunately engineering is not perfected to the state of being an exact science which would make the design of a pumping plant a simple mathematical problem. Published literature shows that opinions differ greatly in the methods used to arrive at these estimates.

The following discussion includes four items which must be estimated in the design of a sewage pumping plant:

1. The *design capacity* of the plant
2. The *flow rate* of the sewer system
3. The *pump capacity*
4. The *reservoir capacity*

Sewage pumping plants can be broken down into two classes: one without storage, the other with storage. The type without storage is suitable in cases where there is a large flow of sewage with a small change in rate of flow. The type with storage is suitable for any type of flow.

The methods which will be discussed are well suited for economical design of a pumping plant using storage. Also, some of these methods apply as well to a pumping plant without storage.

Design Capacity

The first thing that must be estimated is the *design capacity* of the plant. The design capacity is defined as the planned total daily flow through the plant. This capacity is based on tributary area, the limits of which are defined by the natural terrain or the sewer layout.

The flow from any given tributary area may be estimated in either of two ways:

1. Based on population;
2. Based on zoning characteristics.

The first method is best suited for residential areas, while the second method is best suited for commercial and industrial areas.

If the past and present populations are available in the Federal census, the future population can be estimated by expanding the population along a biological growth curve.

If the estimates are to be based on zoning, consideration must be given to terrain and environment. This means accounting for such features as rivers, hills, transportation, and utilities.

The basic flow units, such as G.P.D. and C.F.S. per acre, may be based on actual measurement of similar areas, such as sewer gaugings and previous pumping records, or on zoning coefficients when available. The flow to be considered should be the average of the three peak months of the year; for the Los Angeles areas these are January, February and March.

Flow Rate

Having arrived at an estimate of the average daily flow, it is now necessary to determine how this flow will arrive at the site of the pumping plant. The best method to do this is to draw a flow rate curve as illustrated in Fig. 1.

The flow rate curve is a curve which defines the rate of flow at any hour of the day. The average rate of flow is shown on the curve.

The curve shown here is a typical curve of a normal rectangular residential area. One extreme curve may be found in the flow from an Army

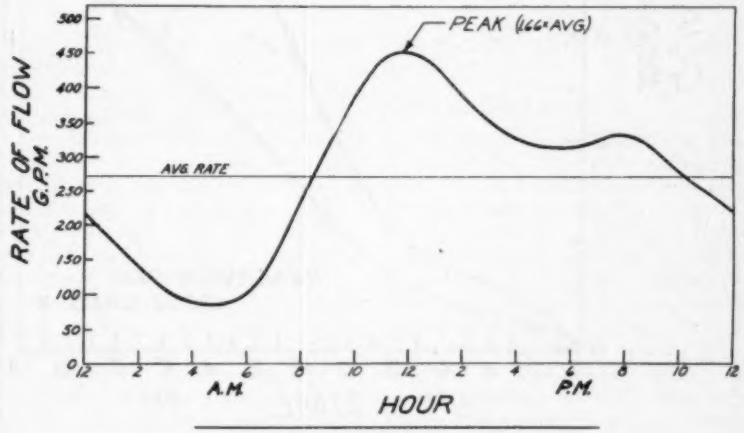


Fig. 1—RATE CURVE for sewage flow
This curve is typical of a normal rectangular residential area.

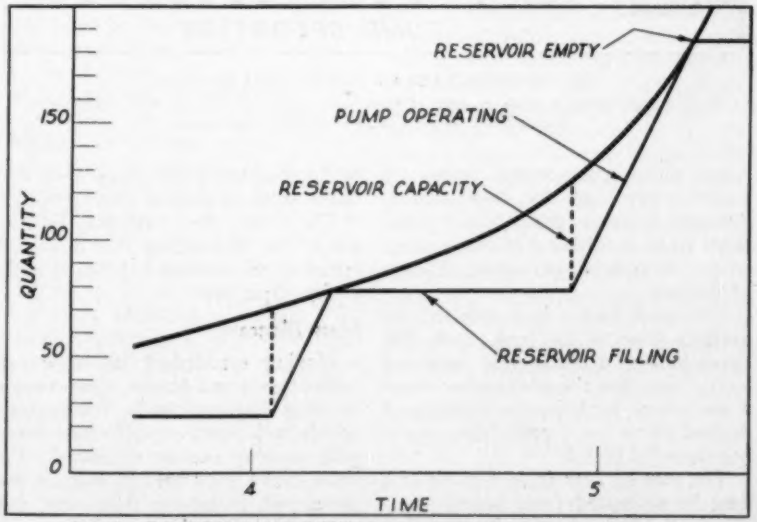


Fig. 2b—EXPANDED MASS CURVE Fig. 2a for plotting pumping frequency
Pump operates at fixed rates when reservoir is filled to capacity.

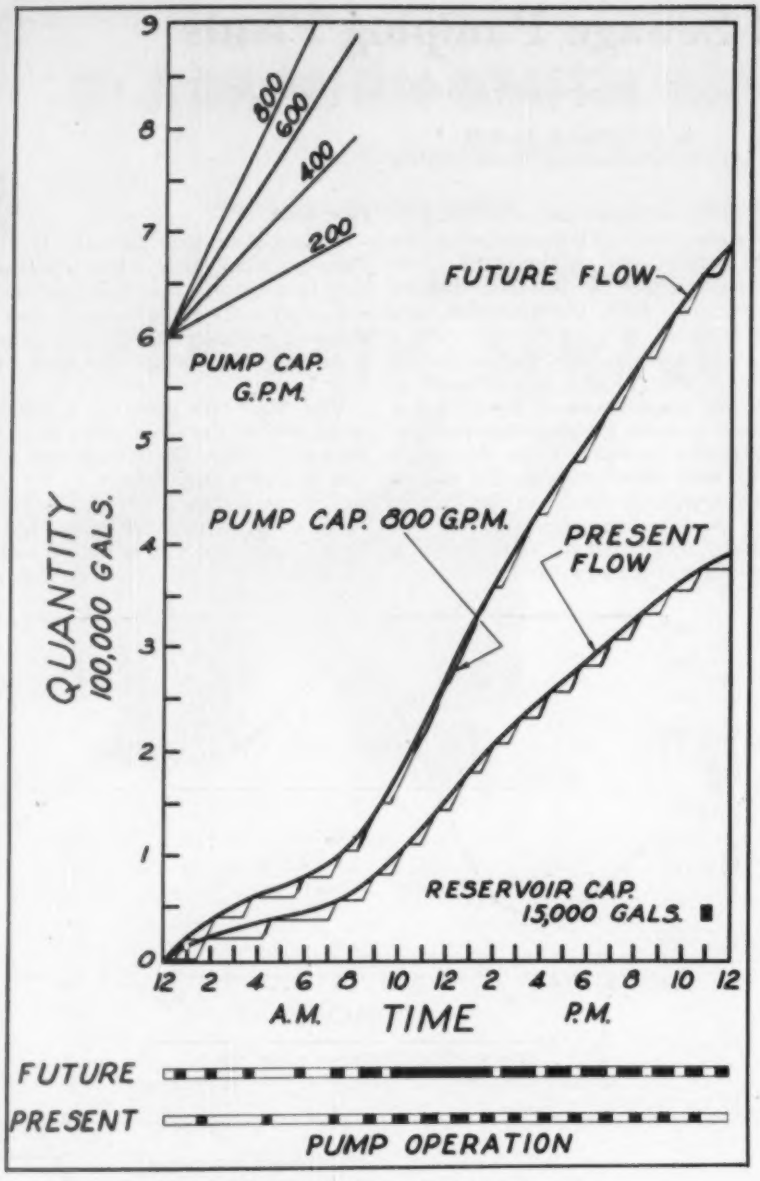


Fig. 2a—MASS DIAGRAM developed from rate curve
Slope of curves is equal to rate of flow (ten year future is 1.8 times present). Below: Solid dashes illustrate pumps in operation.

camp where exaggerated peaks are found every time the bugle blows. Another extreme case is found in the flow from a 24-hour packing plant where the flow is constant at all times of the day.

The peak factor is a ratio of the average flow to the peak flow. The curve in Fig. 1 has a peak factor of 1.66. Note that the curve also shows a secondary peak in the evening. A normal curve has a peak factor varying from 1.3 to 2.2.

The rate of flow from a given area may be estimated from actual measurements, or by considering the time of concentration of the sewer system, or by comparing the given area with other areas of similar characteristics.

The future flow rate may be estimated by expanding the flow rate curve by the increase calculated in the design capacity.

Mass Diagram

Having established the flow rate both present and future, a mass curve or mass diagram can be drawn, from which both pump capacity and reservoir capacity can be estimated. The mass curve illustrated in Fig. 2a was developed from the flow rate data comprising Fig. 1.

The mass curve is defined as the accumulated inflow at the pumping plant at any hour of the day, and is derived by integrating the flow rate curve from any zero hour, in this case considered to be 12 o'clock midnight. This means that the area under the flow rate curve between zero hour and any time of the day is equal to the ordinate of the mass curve. Another way of stating this is that the mass curve defines the total amount of sewage that arrives at the pumping plant between zero hour and any specific hour of the day.

Thus the slope of the mass curve equals the rate of flow. It is these two features that make it possible to plot a picture of the operation of a pumping plant and therefore pick a good combination of pumps and reservoir capacity.

At this point, I should add that it is necessary to estimate the life of the structure and pumps. A reasonable life for the structure is 40 years. However, some engineers like to use 50 and 60 years.

Authorities differ considerably on what is a reasonable life of a sewage pump. For secondary reasons, ten years will be considered the life of the pump in this example.

As you can see on the diagram (Fig. 2a), there are two curves. One is the present flow, and the other is the flow ten years from now, or 1.8 times the present flow. For simplicity, this is to be considered the ultimate flow.

Pump and Reservoir Capacity

An expanded section of the mass curve (Fig. 2b), shows how the pump operation can be plotted directly on the curve. As mentioned before, the ordinate of the curve equals the accumulated inflow. The slope of the curve equals the inflow rate. The pump capacity is the slope of the pumping line. The storage capacity is a fixed ordinate. The time is measured on the abscissa.

Starting at a point on the mass curve, a horizontal line is drawn to the right. This represents the filling of the reservoir; it is considered full when the difference between this line and the curve equals the storage capacity, a vertical dotted line. From the point on this line where the reservoir is full, a line is drawn with a slope equal to the pump capacity. This line represents the pump in operation. At the point where this line intersects the mass curve, the pump shuts off and one cycle is complete. The picture now shows the time that the pump is idle and the time that the pump is in operation.

To help in picking a suitable pump, a series of pump capacities is drawn

in the upper left hand corner of the diagram (Fig. 2a) making it easy to choose a pump capacity which closely matches the mass curve.

The example shows the plotting of pump operation for the entire day. This is done for a given storage capacity and pump capacity. If the operation is not suitable for the capacities chosen, they may be altered and the operation plotted again. This is done for both present and future curves.

If a straight line is drawn between the two end points of the mass curve, it would represent a pump capacity which would just handle the total daily flow and never shut off. However, a quick glance at the storage capacity necessary will show how impractical this combination would be.

At the bottom of the diagram you can see two dashed lines. This is done to show a clear picture of the operation. The solid area represents the pumps in operation. Thus a solid line would indicate the pump running continuously.

In this manner the pumps and reservoir are actually fitted to the sewage flow, thus making an economical design.

This method is not new, for it was used in other ways long before I was born. However, I feel that it still provides a good straightforward approach to the design of a sewage pumping plant.

Garden Hose for Pump Packing

An economical and long-wearing material

By WM. H. HIGGINS
Supv.-Mgr., Ewing-Lawrence Sewerage Auth., Trenton, N.J.

IN our sewage treatment plant we have two sludge pumps of the piston type that leaked very badly. Our pump room floor and pumps were always messy and wet which also gave an impression of poor housekeeping. The packing would again leak very badly a week after renewal and within four to six weeks would be completely worn out. This frequent changing of packing naturally runs the maintenance costs of these two pumps extremely high; in fact, way out of proportion to costs of maintenance of other equipment.

Having heard or read of the use of garden hose for packing, we decided to try discarded 5/8" garden hose in place of the 3/4" packing, after having tried several types without much to choose between any of them.

Preparation and Use of the Garden Hose

You first "soak" the hose thoroughly in oil so it will slide more readily; then, cut it to the approximate length. A piece of wood about 2" wide and 1/2" thick, with the length most convenient to the user, is lowered to the bottom of the stuffing box and marked to indicate the top of the stuffing box. With this marked stick, when the first ring of packing is in, you will be able to tell whether it is "driven" all of the way down in the box.

Using the above piece of wood, the length of hose is placed into position and "pounded" in about an inch or two. Here an exact measurement is made of the hose length and *cut perfectly square*. This is important in order that the hose joints will bind very tightly together when hose is pounded into its final resting place. It might be well to note that we seem to treat the hose very roughly by pounding or driving it into place. This hose is ring shaped and we are trying to fit a round object into a container made for a square object. I feel that it is necessary that it be understood that this garden hose will not fall into place or be easily pushed into place. A lot of effort will be needed to accomplish this job.

Of course, the joints of the hose rings must be staggered and each ring put in exactly as the first. As each ring is put in it will be necessary to use a pinch bar or the like in order to get this hose to start down the stuffing box, because of its tight-fitting nature. In other words, you have to pry the hose into its initial start down the sides of the cylinder and then it is pounded down with the piece of wood mentioned previously.

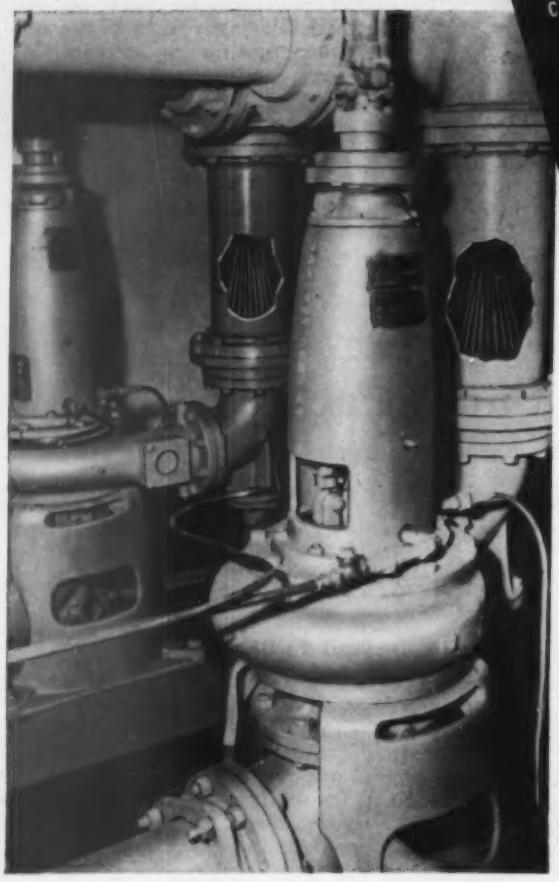
In using scrap hose there might be a slight variation in its size even though it is called 5/8" hose. We found in one pump that four rings were needed and only three in the other. Eventually (possibly in two to three months) the fourth ring will have to be added.

Don't Be Discouraged

The pumps will leak for a short period of 2 to 3 days. Be patient and you will find the leakage will stop. Then a slight backing up of packing glands might be necessary. If the pump seems to be laboring, this is the clue that the packing is too tight. The hose will in a short time square up just like regular packing. Be sure that oil is kept in the packing gland reservoir as customarily done when regular packing is used. We have found that rubber hose lasts longer than plastic hose.

In conclusion, I would like to inject a thought that I have had on my mind since a remark was passed that only a "cheap" outfit would use garden hose as a substitute for good packing.

I sincerely believe as an operator of a sewage treatment plant that we are employed not only to run the plant properly, but also to use a little discretion and practice economy in purchasing parts, etc. We, as operators, must realize the cheapest is not always the most economical nor is the dearest always the best in regards to materials. In sewage treatment those who care for and maintain equipment should always be open for new ideas, and there is a real need for new ideas. We therefore are obligated to try new ideas and experiments.



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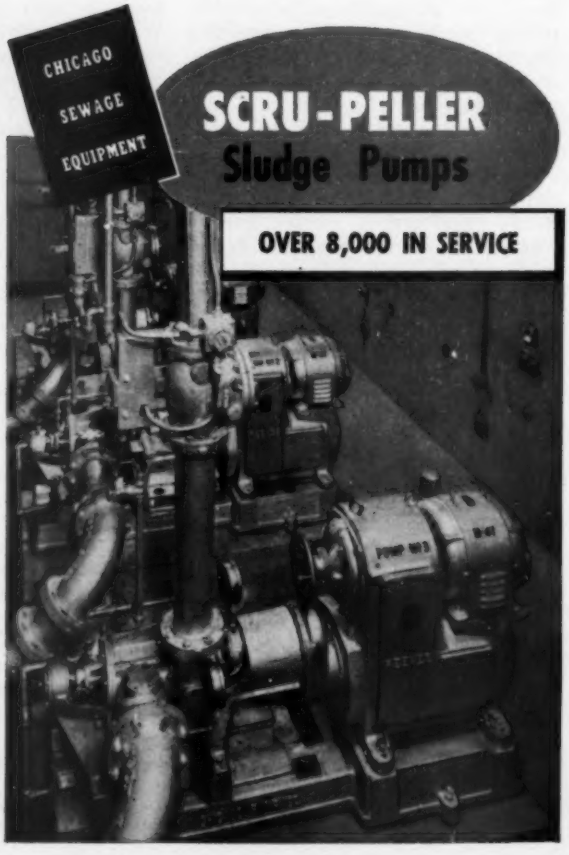
One of 11 Flush-Kleen Lift Stations installed in the City of Portland, Oregon. The discharge line has been cut away to show the strainer. These stations were designed by Stevens and Koon for the Engineers Portland Sewerage Project.



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Sewage and Sludge Pumping

By HENRY RYON
Late Senior Engineer, State Department of Public Works, Albany, N. Y.

Part I—Sewage Pumping

DURING the past decades a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addititon to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars, running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well

should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or or even 100 feet. Beyond this head two stages are needed, but the ordinary tvpe of multi-stage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistance greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallons per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a common suction header must for the same reason be made at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a sources of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Part II—Sludge Pumping

Pumps designed for moving or lifting sewage sludge may, in general, be divided into two distinct classes, displacement pumps and centrifugal pumps. Since these two classes differ radically in their design and operation and present entirely different problems for those in charge of them, it is necessary to consider them separately. The advantages and disadvantages of each class are matters which engineers and operators are not entirely agreed upon. Displacement pumps are unquestionably more easily primed than centrifugal pumps when there is a suction lift and will probably handle small quantities of sludge more readily than centrifugal pumps, but beyond this it is doubtful whether the advocates of either class will admit the superiority of the other.

Displacement Pumps

The modern displacement pumps used for handling sludge are always of the single acting reciprocating type, and are usually electric motor driven plunger pumps having one, two or more cylinders. The makes most commonly used generally have cylinders about ten inches in diameter and strokes adjustable from about two to five inches. The pumps are connected to the motors by gears, belts or chains and the motion transmitted to the pistons by walking beams or eccentrics.

Transmission

Certain matters in connection with the transmission are, however, of importance. If it is desired to have the pump run smoothly it is usually best to keep the speed of the main pump shaft below about thirty-five revolutions per minute. This gives a piston speed of thirty feet a minute or less, a low figure as compared with the usual figures for water pumps; but the strokes of these sludge pumps are very short and the frequency of the reversals seem to be of more importance than the actual piston speed. Pumps of this type are generally arranged so that the length of the stroke can be changed by shifting an eccentric or, which amounts to the same thing, altering the length of the crank arm. This makes it possible to obtain several different rates of discharge, but experience indicates that the use of the shorter strokes is not always entirely satisfactory. The pumps in most cases do not operate as smoothly with the short strokes as with longer ones, the slip

is greater and the efficiency lower. The use of multi-speed motors and variable speed transmissions, although more expensive, afford a more satisfactory and efficient method of changing the pump capacities to suit the conditions, and where available should be used in preference to changing the length of the stroke.

Packing

Like all reciprocating pumps the sludge pumps must be packed to prevent leakage between the pistons and the cylinders, and this packing is one of the most frequent causes of trouble in the operation of the pumps. The packing may be either on the cylinder or the piston. Generally it consists of from 4 to 6 rings of ½ inch to ¾ inch packing held in place by an adjustable metal ring or gland. If the packing is too tight, scored pistons or cylinders and broken shear pins will be the result. If the packing is too soft, too loose or improperly placed it will leak, and since the pumps are outside packed this means that the pumps and probably the floor around them will soon be covered with sludge which does not add to the attractiveness of any sewage treatment plant. Opinions differ as to the most satisfactory type of packing. Generally a square braided flax packing serves as well as any. A graphited packing may be desirable to prevent unsatisfactory conditions due to rust where the pumps stand idle for a considerable time. Rawhide packing is satisfactory but does not seem to be necessary except with certain chemicals. The packing must fit and must be properly placed. In cutting the packing it is well to use a template into which a piece of packing exactly the length of one ring can be fitted. In this way each ring will have the same length and the same bevel. The method of oiling the packing varies with the make of the pump. Generally it is found that a fairly heavy oil such as a good grade of cylinder oil gives the best results. Oils known as "500 W" and "Marine Pump Oil" are in common use. A light oil disappears very rapidly. Under continuous operation the packing will usually last about 3 months, but under intermittent operation it may last a year or two. Manufacturers have recently been giving more attention to the finishing of the pistons and cylinders, in some cases grinding them. This has made it easier for operators to keep sludge from leaking between the pistons and cylinders but has not done away with the necessity for careful packing.

Valves

Each cylinder of a reciprocating pump necessarily has an inlet valve and a discharge valve. These valves may be weighted flap valves or ball valves. Each type has its advocates although at present the ball valves seem to be preferred by most operators. Spring loaded poppet valves which operate satisfactorily in water pumps obviously cannot be used for liquids containing an appreciable amount of solids. No matter which type is used the valves will require some attention from the operator. With raw sludge the valves may require cleaning from two to three times a day to two or three times a week. If the pump is handling activated or secondary tank sludge, cleaning will of course be required less frequently. Fibrous material will collect under the hinges or flap valves and rags will accumulate under ball valves holding the valves off their seats and rendering the pump inoperative. Metal flap valves wear at the hinges so that the flap will not seat properly and soon require replacement. Valves of rubber with rubber hinges clog less frequently than metal valves because of their smoother surfaces, but the rubber hinges are inclined to swell and split and it is difficult to turn them back for cleaning. Ball valves are usually of rubber moulded on an iron core. If they are to operate satisfactorily, careful attention must be given to the quality of the rubber, the balance of the valve and the weight of the core. Valves made of a poor quality of rubber will sometimes swell and stick, and cases are on record where the rubber has softened so as to allow the ball to be forced into the piping stopping the pump. The valve must balance or the ball will always seat at the same point and wear rapidly. The weight of the valve must be suitable for the conditions under which it will operate.

Pounding or Knocking

One of the most frequent complaints heard regarding the operation of reciprocating pumps is that they knock or pound. This is due to various causes. Since sludge lines are usually comparatively short, the high water hammer stresses sometimes encountered at water pumping stations are seldom of importance, but the flow of liquid in the suction and discharge lines must be stopped and started with each stroke (single cylinder pump with no air chamber), the valves must close and in doing so strike the seat, and each stroke causes a reversal of stresses in the piston, the crank and the connecting mechanism. These conditions cause pounding which cannot in all cases be entirely eliminated. The subject is too complicated to be discussed in detail here.

The stresses and pounding due to starting and stopping the flow in the discharge line can be generally alleviated by the use of an air chamber, but the air chamber must be large to be of any value. The same thing is true of the suction line, although an air chamber is not so frequently used at this point. One manufacturer provides a small air inlet valve on the suction of the pump which if properly adjusted seems to make the pump operate more smoothly, but of course somewhat reduces its capacity and efficiency.

Valve slam is sometimes due to the fact that the direction of flow through the valve reverses and acquires considerable velocity before the valve closes. This velocity may then carry the valve to its seat rapidly enough to cause a heavy blow when the motion of the valve and the liquid is suddenly stopped. This reverse flow of water through the valve is of course slippage and reduces the efficiency of the pump as well as causing valve slam. The valve should, for these reasons, be heavy enough and so arranged as to close as quickly as possible, and yet not interfere with the operation of the pumper by reducing the area of the ports.

The knocks due to the reversal of stresses in the different parts of a pump are the same as those which occur in any reciprocating machine. If there is any lost motion in a main bearing, eccentric, wrist pin or other part there will be a knock each time the stresses are reversed. The remedy is obvious. All bearings must be properly adjusted and kept properly lubricated.

Centrifugal Pumps

Centrifugal pumps, if they are to handle sludge successfully, must pass solids without frequent clogging. This makes it necessary to use end suction pumps at least 4 inches in size with as few bends and sharp corners in the liquid passages as possible. The impellers usually have only two blades with long sweeping curves and are either fully enclosed or have a shroud on one side. Open impellers clog very rapidly when the liquid contains rags. Even with these precautions, it is generally desirable to have hand holes or other means of access to the interior.

One pump manufacturing company equips its centrifugal sludge pumps with a screw to force the sludge into the pump and to macerate the solids as they enter. Pumps of this type have been in operation at a number of plants for several years. Similar devices are being made by some other manufacturers but have not as yet come into extensive use.

Capacity and Regulation

A 4-inch centrifugal pump will readily discharge 100 gallons a minute and in some cases as low as 50 gallons a minute, but if capacities below this are necessary some difficulty is apt to be experienced unless provision is made for reducing the speed below that which can be obtained by a direct connected motor. Variations in head, of course, cause variations in the capacity of a centrifugal pump and if a definite quantity of discharge is required some method must be provided to compensate for these variations. In many plants it is necessary to change the quantity of sludge delivered from time to time and provision must be made for so doing. Theoretically, throttling might accomplish these ends, but throttling is not desirable when pumping sludge. If careful adjustment of the quantity of sludge delivered is necessary the only practical method of regulation seems to be to change the speed of the pump. Variable and multi-speed motors will do this within limits but are not as satisfactory as some of the variable speed transmissions available. These transmissions, while expensive, make it possible to obtain almost any capacity within the limits of the pumps. It must not be forgotten, however, that a centrifugal pump will give its highest efficiency at one definite speed and capacity and that as the speed and capacity are changed the efficiency may fall off rapidly. This is naturally of more importance when the pumps are in continuous operation than when they are operated intermittently.

Priming and Seals

Centrifugal pumps will not handle air, and when they are used careful consideration must always be given to priming and to the elimination of air pockets in the suction line. To facilitate priming, centrifugal pumps should if possible be set below the surface of the liquid in the suction well. If the pump must be set above the level of the liquid some means of priming must be provided. Foot valves which are often used with water pumps will not serve satisfactorily with pumps handling sludge. Vacuum systems are available and operate satisfactorily if kept in condition, but mean added expense of installation and more equipment for the operator to maintain.

The impeller shaft of every pump of this kind must pass through the pump casing and therefore requires a stuffing box to prevent leakage. On water pumps these stuffing boxes are provided with water seals and the water taken from the pumps. The material handled by a sludge pump is not, however, suitable for the seals and water must be obtained from some source. A direct connection to the water system cannot be used due to the danger of polluting the water supply with sludge. If the building is high enough a small tank fed over the top and controlled by a float valve may be used as a source of water. The height of the tank must be greater than the discharge head of pump or the sludge will be forced into the packing and probably result in the scoring of the shaft. If the tank cannot be set high enough, a pump may be used to supply water to the seal.

Locating Lost Sewers and Manholes

By E. T. CRANCH
Director, Department of Public Works, New Rochelle, N. Y.

IF YOU have sewers, drains and manholes for which you have no records or for which available records are inaccurate, then, perhaps, some of the experiences recounted here may be of practical interest.

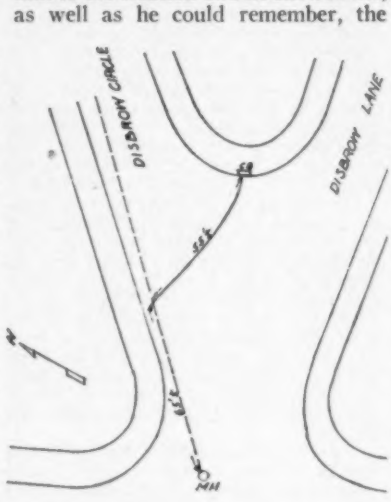
The settlement of New Rochelle, New York, was started in 1688, and it has enjoyed a consistent and rapid growth since then. It was incorporated as a village in 1858 and became a city in 1899. The 1940 federal census gives the population as 58,408. The area of the city is 10½ square miles.

The population area of the city has largely expanded by individual real estate developments to which were assigned definite names, such as Residence Park, Halcyon Park, Highland Park, etc. In the early days, each real estate developer tried to be exclusive and laid out dead end streets. The streets were laid out with the definite intention of not connecting with the streets of any other development. Within recent years this situation has been corrected by the creation of a city planning board which has set up a master city plan, and every developer must have his plans approved by the planning board before he can start work; also, all plans for sewers and drains must now be approved by the Department of Public Works and the construction inspected by that department.

For many years, however, sewers and drains were installed by the developer under no city supervision; no maps were submitted to the city, and in some cases I have found the developer had no map showing the course of the pipe. I have found instances where the developer has laid pipes across lots, and when he sold the properties crossed by the pipe he retained no easement covering the repair or maintenance of the pipe.

I have found one instance where in 1894, by order of the Board of Health, the city laid a 15-inch drain meandering along the course of a brook across lots, filled in the bed of the brook over the pipe and never secured any easements from the property owners. A few years ago it became vitally necessary to increase part of this drain to 36 inches, and the city had to pay a substantial amount for the easement, although the 15-inch pipe had been occupying the same property for over forty years.

I have had occasion to investigate a situation where there were constantly recurring floods. I found a 24-inch vitrified tile drain completely plugged. From a point where an open brook entered this pipe, it was approximately 1,000 feet to the first manhole. The city had no plan of this drain. I contacted the developer and found he had no plan, but I took him to the location and he showed me, as well as he could remember, the



Location of point of intersection of catch basin lateral and main drain simplified by use of M-Scope at New Rochelle, N. Y.

course of the drain, which, it seemed, followed a reverse curve. The drain was laid with open joints, and went through a swampy area in which there were a number of willow trees.

This led me to believe that the stoppage was in all probability caused by the entrance of willow roots into the drain. This spot was too far away to be reached satisfactorily with flexible sewer rods from either opening in the drain. We therefore decided to put in a manhole in the swamp area. After four days of digging we finally located the drain at a depth of about 5 feet and opened it. We found the pipe completely filled with roots and it took almost two weeks of work to clear the line. This experience made me feel that there ought to be some means of locating underground sewers and drains.

I was familiar with the use of the M-Scope in locating underground water mains. So I asked the salesman to try it out on this drain with flexible sewer rods inserted in the drain. We got 238 feet of rods in the drain, placed the transmitter on the rod and also, by means of the wire and clip provided, connected it to the rod. With the receiving set we were able easily to follow the course of the curving drain for about 200 feet. At this distance the signal became rather faint, but one man with keen ears followed it for the full distance of 238 feet.

We then rigged up the transmitter and receiver on the carrying sticks and went over the line to see if by any chance we might find any hidden manholes. At one point, right over the line, we got a sharp signal and started to dig feverishly for the manhole, only to find that a steel barrel hoop was buried in the ground. However, this demonstration satisfied me that the instrument could be used satisfactorily, for the purpose of locating both tile drains or sewers and buried manhole covers.

At another time, to relieve a flood condition, we wanted to install a new catch basin in the middle of a block and connect it to an existing drain at a manhole shown on the map at about the point we wanted. There was, however, no evidence of the manhole on the ground. With the M-Scope we located the manhole within a few minutes, just off the paved area, and under about 3 inches of sod. This time it was really the manhole.

Another time the map showed a drain manhole on the east side of the street at a certain intersection. The M-Scope gave no signal on the east side of the street but gave a clear signol on the west side of the street and, sure enough, we found the manhole about 8 inches deep under the macadam pavement.

We had a sewer and a drain running through a private right-of-way. The map showed a manhole on each. The sewer and drain had been installed 14 years ago. For the past several years periodic efforts had been made to locate the manholes, but without success. This right-of-way had several angles in it. It passed through a fine estate and the property was so thickly landscaped with evergreens, paths, gardens, etc., it would have been almost impossible to have resur-

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veyed the right-of-way without doing real damage to the property. With the M-Scope we located and uncovered both manholes within an hour. One manhole was covered with about a foot of dirt and the other with about 3 inches.

Another time we tried to follow the course of a drain, about 15 feet deep, which ran through territory covered with thick brush, so that it was impossible to follow the line directly from the manhole. The first open land was almost 200 feet away from the manhole and transmitter, but no signal whatever could be picked up there. We cut an opening in the brush about half way back, and were able to pick up the signal at that point. For deep drains it is necessary to limit the distance from the transmitter.

Another failure we had was in trying to find a couple of catch basins that we thought were located near an abandoned railroad bridge, where the land is thick with brush. Following along the gutter we picked up a signal on each side of the road and thought we had located the catch basins, but digging down we found nothing. I then found I could follow the signal across the road. There is a 24-inch drain at this point, installed by the old railroad company, and apparently 24-inch cast iron pipe was used to cross the road. This experience illustrated the fact that in locating catch basins or manholes, when a signal is picked up, it must be tested from every direction to see that it is not emanating from a pipe line.

In a road improvement job we had a 15-inch storm drain in the road and a catch basin on one side of the road with a lateral connecting to the drain at an unknown point. We wanted to install a new catch basin on the opposite side of the road, connect this basin to the drain at the same point as the lateral from the old catch basin and build a manhole at the junction of the three lines. The accompanying sketch illustrates the condition we faced. We ran the flexible rods through the lateral from the old catch basin and, much to our surprise, found that it followed a curved line. As a check for the point of intersection, we ran the rods up the 15-inch drain from the manhole at Webster Avenue and located it on the ground. At the indicated point of intersection we dug down and found ourselves at the exact point desired. If we had simply assumed that the original lateral had been laid on a straight line as it should have been, we would have dug for days before we would have found the right spot.

We have also used the M-Scope to trace the meandering drain laid in 1894 and mentioned at the beginning of this paper. Here the instrument proved very effective and also located two manholes which had long been covered along its course.

In conclusion, I will say that I have found the M-Scope very effective for locating the position of shallow drains for distances of about 200 feet, and for deep drains about half that distance. It is excellent for locating manholes as long as care is used in its operation, and it is understood that it will pick up any metallic substance underground, be it manhole, barrel hoop or pipe line.

Size and Slope of Sewers—A Simplified Formula

By BENJAMIN EISNER, Ch. Engr.
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KUTTER'S formula for computation of flow velocities in open channels is preferably solved by graphs to avoid the lengthy arithmetic necessary to compute "C." Because pipe sewer problems are but a small portion of the wide field of application of the Kutter formula, and since extreme precision is not warranted in sewer and drain design, it is possible to approximate the Kutter formula for such problems by matching a simple curve to the complex one expressed by the formula. Such matching is possible only because short lengths of the curves are used. For sewers and drains "n" is usually taken at either 0.013 or 0.015; "v" is required to exceed 2 feet per second, pipe diameters generally fall between 8 and 36 inches, and slope rarely reaches 10 per cent grade.

If within these limitations, values for "s" are plotted against "d" for any given velocity, the resultant curve closely approximates a hyperbola. If too, for later convenience, "s" is measured in feet per thousand, and "d" in inches of diameter, the hyperbolic curves may be expressed in the following manner:

For "n" = 0.013: $v = 1/2\sqrt{s}\ \sqrt{d-4.5}$ (A)

For "n" = 0.015: $v = 4/9\sqrt{s}\ \sqrt{d-5}$ (B)

Of course, both cases apply only to pipes running full or half-full. Accuracy of results by use of these approximations is indicated in tables I and II which cover the range of application outlined above.

Use of these approximations with a slide rule is believed to be quite as rapid as use of charts for the solution of Kutter's formula. Although there is a slight loss of accuracy, the error thus introduced is less in amount than the errors accompanying estimates of future flow and choice of coefficient "n."

So far, no mention has been made of the term Q as used in $Q = Av$. If Q is measured in million gallons daily, if "d" is used as before, to denote pipe diameter in inches, and if the pipes are considered to run full, $Q = Av$ can be reduced to

$$d = 17\sqrt{\frac{Q}{v}} \qquad (C)$$

which is easily converted to a form suitable for rapid determination of pipe size for minimum self-cleaning velocity. If velocity of two feet per second is the lower limit, this expression reduces to $d = 12\sqrt{Q}$, for full flow, which can be further simplified by expression as "diameter in feet for 2 feet per second velocity equals the square root of the full flow in millions of gallons daily." Similarly the previous approximations for "s," at 2 feet per second velocity reduce to the fllowing—

For: $(n = 0.013)\quad s = \dfrac{16}{d-4.5}$

For: $(n = 0.015)\quad s = \dfrac{20}{d-5}$

Thus for minimum self-cleaning velocities determination of diameter and slope is rapid.

Commitment to memory of approximatoins (A) and (C) permits rapid sewer and drain design when flow charts are not readily available. For the slight loss of accuracy, speed and convenience are gained. In practical use "d" is assumed and approximate "v" determined as in (A).

This value is substituted in (C) and the result "d" is compared with the assumption. With slight practice the second trial value of "d" will be found to satisfy both equations within practical limits.

Comparison of Velocities of Flow in Conduits (Running Full or Half Full) Computed by Approximate Formula and Kutter's Formula

TABLE I (n=0.013)

SLOPE (Feet per 1,000 ft.)	DIAMETER (Inches)				
	8	12	18	27	36
0.1			**0.8** 1.0	**1.3** 1.5	**1.9** 1.9
1	**0.9** 0.9	**1.4** 1.4	**1.9** 1.8	**2.6** 2.5	**3.8** 3.9
2	**1.6** 1.7	**2.6** 2.6	**3.2** 3.2	**4.5** 4.5	**6.9** 7.2
10	**3.9** 3.2	**6.3** 6.3	**8.8** 7.5	**7.9** 7.8	**8.9** 9.0
20	**5.5** 5.5	**7.8** 7.5	**10.1** 10.1	**12.0** 12.5	
100	**9.4** 10.0	**13.7** 13.8			

TABLE II (n=0.015)

SLOPE (Feet per 1,000 ft.)	DIAMETER (Inches)				
	8	12	18	27	36
0.1			**0.9** 0.9	**1.5** 1.5	**1.4** 1.4
1	**0.9** 0.6	**1.2** 1.1	**1.6** 1.5	**2.1** 2.1	**2.9** 2.9
2	**1.3** 1.4	**1.9** 1.9	**2.8** 2.7	**3.9** 3.6	**4.3** 4.4
10	**3.0** 2.6	**4.4** 3.6	**5.9** 4.9	**6.6** 6.6	**7.9** 9.1
20	**4.3** 4.5	**5.9** 6.2	**8.0** 8.2	**11.4** 11.2	**11.6** 11.6
100	**7.2** 8.2	**11.7** 11.2	**16.8** 15.5		

Bold face figures indicate approximation. Light face figures are results from chart of Kutter's Formula.

Maintenance of Plant Equipment

I. Pumping Station Equipment

By J. M. MacCREA
Chicago Pump Co., Syracuse, N.Y.

IT IS of utmost importance that all operators form the habit of keeping their mechanical equipment in good repair. Half the battle has been won if an operator will train himself to recognize potential trouble and then do something about it before it grows into a full-fledged monster. Just as preventive medicine plays so vital a role in control of human disease, so also does preventive maintenance play a most important part in keeping mechanical plant equipment operating at peak efficiency.

Manufacturers strive to provide the best designed, most dependable equipment to do a particular job. For each piece of equipment, the manufacturer provides complete instructions on proper operation and maintenance, including the following items:

1. Information on the proper method of installation, as proper installation is prerequisite to proper functioning.
2. Lubrication instructions, which should be studied and carried out before the equipment is placed in operation.
3. An explanation of proper operation, so that improper operation may be recognized, as well as pointers enabling location of any reasons for failure.
4. Procedures for dismantling and reassembling for repairs.
5. Parts lists and repair order instructions.

In brief, the operator is provided with the essentials needed to institute a program of preventive maintenance in his plant.

Early Appointment of Operators

To those who are charged with management of new sewage treatment plants, it cannot be too strongly urged that the operators be appointed at the start of construction so they may watch and study the equipment as it is erected. Furthermore, the annual budget should include the necessary funds to enable the operators to institute and maintain an effective preventive maintenance program. The equipment suppliers usually are more than happy to cooperate in setting up check lists for preventive maintenance for their units. And such check lists could profitably be set up even in small plants; in the larger plants such a program is imperative.

Proper Erection Required

An installation and operation instruction booklet is a part of each piece of equipment shipped. The first function of this booklet is to instruct the installer on the proper procedure to follow for erection of the unit. Yet, in fully 50 per cent of the cases the installer will claim the booklet was never received. On occasions, however, it has been found still attached to the equipment; on other occasions it has been found trampled in the mud outside the construction shanty.

Proper erection is the first requisite in preventive maintenance. Float control assemblies must be properly aligned so that the rods will ride free. All equipment must be set level and properly aligned. Despite provision of flexible intermediate shafting in pumping equipment, the complete assembly must be installed plumb and level if excessive maintenance costs are to be avoided. That alone is sufficient reason for having an alert operator, who is preventive maintenance conscious, on the job during construction.

Types of Pumping Stations

Few if any communities are fortunate enough to be so situated that their sewer systems and sewage treatment plants can be designed without the use of pumping equipment. With the ever-increasing expansion of residential areas into outlying districts, more and more small lift stations, and often fairly large lift stations, must be employed. These stations fall into the following classes:

1. Small submerged pump stations utilizing vertical, enclosed shaft, nonclogging pumps. For use of this type of station most State Health Departments require some sort of protection ahead of the pumps, such as a hand-raked bar screen in an adjacent manhole, or a removable basket screen over the inlet in the wet wall, or pumps employing built-in screen protection.
2. Small pump stations with separate wet and dry pits, with the pumping equipment located in a compartment separate from the wet wall. Suitable screening protection also is required in this type of installation.
3. Medium and large stations located at remote points from the sewage treatment plants and utilizing three or more pumping units with varying capacities designed to meet the requirements of flow fluctuation. These stations often are large enough to justify use of automatically-cleaned screens or comminutors to properly protect the pumping equipment.

This paper is confined mostly to preventive maintenance of equipment in small outlying pump stations. Nevertheless, it must be kept in mind that 4-in. pumps, often utilized in these small stations, must handle essentially the same size solids as the larger pumps are called on to handle. Therefore, an effective preventive maintenance program for a small pumping station would, at least, form a nucleus for a program that would be effective in the larger stations.

Pump Equipment

The maintenance program for these small stations must depend somewhat on the type of equipment involved. Subsurface stations in which all of the equipment, including motors and controls, is located below grade are selected because of lower first costs, or because of the objection raised by people in residential areas to a superstructure which would provide adequately for the electrical equipment. The subsurface pump station may be designed to utilize any of the following types of equipment:

1. Vertical, submerged, non-clogging pumps.
2. Vertical, open-shaft pumps installed in a dry pit with a separate wet well and with motors and controls mounted on an intermediate floor.
3. Pedestal-mounted pumps with motors mounted directly on the pumps and with separate wet wells.
4. Special "package" units employing a steel tank as a wet well.

In all of these types of installations, motors and controls, as well as the pumping equipment itself, operate under damp conditions. It is absolutely essential, therefore, that this type of station be provided with mechanical ventilation insuring an air change in 3 to 5 min. Otherwise, excessive main-

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tenance of motors, controls, and pumps will result. It is imperative that the mechanical ventilation be operated continuously, particularly during the warm months, in order to effectively reduce the amount of condensation encountered in these stations.

Experience has shown that open motors are preferable to totally enclosed motors in subsurface stations, as they tend to dissipate most of the moisture within the casings during the running period, whereas moisture accumulating within a totally enclosed motor cannot escape.

It should be re-emphasized that a primary requisite to an effective preventive maintenance program is the proper installation of the pumps and their component parts, and a thorough understanding on the part of the operator as to the proper functioning of the equipment. Pumps and motors must be set level, pumps should not be subjected to piping strains, intermediate shafting must be installed plumb, intermediate bearings should be mounted on rigid supports, floats and float rods should be accurately aligned with the float switch mechanism, pump casings should be properly vented to the wet well to prevent air binding, adequate provision should be made for effectively sealing the stuffing boxes to keep out grit-laden sewage, and adequate provision should be made to remove any accumulation of water from the dry pit. For the last item it is preferable to use an automatic sump pump.

In vertical submerged pumps the pump is suspended from a hanger pipe attached to the motor floor plate. The impeller is driven by a rigid shafting, utilizing one or more sleeve bearings, depending on the length of hanger pipe, and mounted within the hanger pipe. Pressure grease lubrication of these bearings is preferable. Pressure grease lubrication of the lower bearing, located immediately above the pump casing, serves not only to lubricate this bearing, but also to prevent gritty water from scoring the shaft at this point. This lower bearing, therefore, should be greased at least once each week.

The open-shaft type of pump, or the pedestal-mounted pump, usually employs ball bearings and pressure grease lubrication every two months should be sufficient.

In vertical open-shaft pumps, pedestal-mounted pumps, and horizontal pumps, it is recommended that a brand of packing meeting the specifications "braid over braid asbestos graphited packing" of the proper size be used. To determine the proper size of the packing, take the difference between the diameter of the shaft and the diameter of the packing box, and divide by two. In other words, for a 1-in. shaft and a 1½-in. packing box, ¼-in. packing is required. It should be remembered that packing is a close-fitting bearing and, therefore, requires lubrication. Packing cannot run without leakage or a substitute means of lubrication. In pumping sewage, a water seal has a two-fold function in that it keeps grit and sand from entering the packing box as well as acting as a lubricant. Be sure that the proper number of packing rings are used and that the water seal ring, which is a bronze ring with slotted openings to permit the clear water to reach the shaft, is properly positioned opposite the opening provided in the pump casing.

Since state laws do not permit the use of domestic water supply on these stuffing boxes, other sources of clear water must be provided. An effective water seal should provide a clear-water pressure of 5 to 10 ft. in excess of the discharge pressure on the pump. For pumps operating at lower heads it may be possible to provide the necessary static head on the stuffing box by means of an open tank with a float valve located within the station. Where such an arrangement would not provide the necessary static head, it is necessary to utilize a water seal pumping unit. Such a device should provide for a capacity of 2 g.p.m. per stuffing box to allow for future wear of the packing.

The packing should be kept adjusted so that there is a small amount of leakage. Gland bolts should be drawn up one thread at a time, with sufficient time left between turning each thread for the pressure to be transmitted through the packing, and the resultant rate of leakage observed.

Where a clean-water seal is not available it may be necessary to resort to the grease seal. A constant-pressure type of grease cup would seem to be ideal, but in most cases it is found that grease will not flow effectively with the available pressure. Therefore, it has been found that the common screw type of grease cup, or even pressure grease introduced through a conventional Alemite fitting, is preferable. After the grease has been thoroughly introduced throughout the stuffing box, and proper tension on the packing nuts maintained, weekly addition of grease under pressure is satisfactory on pumps having discharge pressure not exceeding 25 to 30 ft. of head. For pumps having discharge heads in excess of 30 ft., a clear-water seal is indicated if maintenance is to be kept at a minimum.

When the packing nuts have been drawn down to the limit, the pump should be repacked completely. Never add one or two new rings of packing on top of old packing. Never repack a pump that has a scored and grooved packing sleeve, for the grooved sleeve will damage the new packing, causing excessive leakage in a very short time. Replace the packing sleeve if it is worn.

In repacking the pump each ring of packing should be dipped in 600-W oil, and sufficient rings of packing should be packed into the bottom of the box so that, when compressed, the water seal ring will be in its proper position in line with the tapped seal in the casing. When the box is half full, the gland should be drawn up just snug. After packing the remainder of the box, the gland is drawn up snug and then backed off until finger tight. Packing expands with heat, and a box that is more than finger tight when cold will generally heat when started up. When starting up a pump the packing box should be carefully watched to make sure that the leakage of seal water is providing proper lubrication, or that the grease seal is effective.

Motors and Electrical

Motors should be lubricated in accordance with the manufacturers' recommendations and care should be exercised not to over-lubricate, as this is often the cause of motor failure. Many present day motors are equipped with sealed ball bearings requiring lubrication at 3 to 5-yr. intervals. It should be pointed out that over-lubrication of ball bearings with either grease or oil may cause overheating of the bearings and result in excessive wear.

Periodic inspection of all electrical contacts should be made to determine that the contacts are not corroded or pitted. The frequency of inspection will be dependent upon the amount of moisture which may be present in the area surrounding the equipment.

Float Controls

Float controls should be inspected monthly to make certain that the floats are riding free and will actuate the float switches dependably on the rise and fall of liquid in the wet well. If float tubes are utilized, it is necessary to clean the cylindrical floats to prevent the accumulation of grease, lint, etc., from binding the float in the tube. Some operators have introduced a constant stream of water to the periphery of the tube to keep the floats clean. In recent years the use of a

float guide cage directly in the wet well has become prevalent. This enables the operator to flush the float clear of foreign matter with a high-velocity nozzle. This makes it desirable to have water under pressure available at the station to perform this work and to wash down the wet well wall periodically.

II. Transmission Gears

By EDWARD J. SMITH
Superintendent, Sewage Treatment Plant, Niagara Falls, N. Y.

Continuity of good operation of any sewage treatment plant is only possible when the chief operator schedules a good maintenance program. The many new sewage plants being constructed each year, and the new designs being introduced by the consulting engineers, bring forth more mechanical equipment which the Operator has to cope with. If this equipment is not kept in good running condition, efficient operation is impossible.

The Niagara Falls plant is a mechanical plant containing more than $500,000 worth of machinery, which must be kept running 365 days a year. To keep this equipment operating, it is necessary to have a set schedule whereby the equipment is shut down, inspected, and if necessary, repaired. This is not too difficult when the equipment is operating in full view. In some instances, however, it is so well concealed that it is a real problem to get at the source of trouble.

Every operator has to "get the feel" of a new plant and it is natural for him to make a few mistakes; but from these mistakes he profits. A number of problems arose when the Niagara Falls plant was placed in operation. However, the opening staff profited by its mistakes, as well as the mistakes of the designing engineer.

In setting up the maintenance program to take care of the equipment that would be shut down on a set schedule, a man who had a good mechanical background was picked to do the oiling and greasing of all the equipment.

As a typical example of preventive maintenance, at the Niagara Falls plant there are 20 variable speed units of various sizes. Six of these are 10-hp. transmissions for controlling the speed of the screens, six are 1½-hp. transmissions for controlling the brush speeds. Other units control the screw conveyors handling sludge or coal from storage tanks to the incinerators. All of these units are vital components of the equipment and essential to the satisfactory and economical operation of the plant.

The drives in question do not require excessive attention if treated properly. They have a minimum of moving parts, but care should be taken that all bearings, shafts, and driving keys are properly lubricated.

Lubrication of this type of transmission is simplified by means of a system of centralized force-feed fittings, located in two convenient panels at the end of the case. This makes possible thorough lubrication without removing the cover. It was found, however, that with this simplified lubrication system the maintenance man was lubricating the drives too often, so that excess grease was getting on the endless cord V-type belts, which are clamped between hardwood blocks, tipped with leather, that drive the discs. The excess grease was causing the belts to slip and deteriorate. This was found to happen only on the six small transmissions that were concealed and hard to get to. This trouble was remedied by moving the drives to positions where they can still serve their purpose and yet can be reached more readily.

When such a transmission is placed out of service for lubrication, even if the transmission can be serviced without removing the cover, the cover is taken off. This enables the maintenance man to see that the lubrication is going to the right parts, and also gives him an opportunity to check all moving parts to see if any show signs of wear or need replacement. The belt tips should be checked for wear. This indicates if the belt is running true, and helps check that the discs are free and not sticking on the shafts. It also gives an opportunity to clean up any oil or grease that is in transmission box where it could splash on the discs or belts, thus shortening the life of these components.

Before the cover is replaced, the speed control is advanced from low to high speed, while the unit is running, and then back to low speed again. This operation makes certain that the discs are sliding free on the keys and shafts, and that the shifting levers and shifting screws are operating satisfactorily. This operation of preventive maintenance also makes certain that the grease is uniformly distributed over all operating surfaces, thus minimizing wear and corrosion.

If the discs are allowed to run too long at a set speed, without following the above-mentioned maintenance procedure, there is a chance that the discs may freeze on the shafts and require application of considerable force to break them loose. However, since adopting a set schedule of inspection and maintenance, no such difficulty has ever been experienced in the Niagara Falls plant.

Maintenance is a problem for all operators, as there is a high turnover of labor. Men leave the sewage field for more lucrative jobs. It has been found, however, that if a man is given sufficient time and full responsibility for his equipment, and it is required that all work be completed before the machine is placed back in operation, less operating difficulty will be experienced. As an example of what can be done, during the past 15 years of operation very few replacement or repair parts have been purchased for the variable speed drives described. This can be attributed to good maintenance performed by men who are interested in doing a good job.

III. Ventilating Equipment

By EDWARD J. SMITH
Superintendent, Sewage Treatment Plant, Niagara Falls, N. Y.

Many sewage treatment plants have ventilating problems. These problems, no doubt, are relieved to a certain extent by ventilating units used to remove obnoxious odors from the buildings. At Niagara Falls there is a problem of combatting the odors of various chemical wastes sometimes discharged into the sanitary sewer

system. Nine ventilating units, of the exhaust type, are arranged to exhaust air from various points in the plant and discharge it into the annular space between the chimney and the chimney tower.

Ordinarily these ventilating units do not require too much attention, but it is necessary to keep the motor and the bearing on the fan shaft properly lubricated, and see that the V-belts are in alignment. However, it has been found that there is more involved in keeping a ventilating unit in operation than just lubrication.

The first experience along this line occurred in the grit chamber room when the ventilating unit began to give trouble. This unit has a capacity of 18,000 c.f.m., and is designed to draw the gases or other vapors from the two grit chambers, which are now totally enclosed. It can also pick up moisture vapors liberated at the bottom of the vertical Venturi meter.

Close inspection revealed that the fan wheel was badly corroded, thus throwing the wheel off balance. The rest of the unit was in fair condition, although it showed signs of corrosion. A new fan wheel was immediately ordered and work was started to get the rest of the unit in shape. To accomplish this, the interior was given a good sand blasting, thus removing all traces of rust. A coat of paint primer was immediately applied to the unit.

Because of the corrosion problem prevalent in the plant, an undercoating machine previously had been purchased. It was felt that the ventilating unit would give a good test as to how undercoating would stand up under severe conditions. The type of undercoating used was a rubberized sealer, manufactured by the Minnesota Mining Company. The inside of the unit was sprayed, and when the new fan wheel was received it also was sprayed with a coat of rubberized sealer. The wheel was then balanced and installed. This same unit has held up well in operation under severe conditions, operating 365 days a year, for the past four years.

The other larger units, operating under similar conditions, have all been cleaned and undercoated. Also, the ventilating ducts have been sealed with undercoating.

This undercoating sealer has worked out successfully on old equipment, and has cut down maintenance cost and labor. It is believed that the life of new equipment would be increased if this material was used on it.

IV. Clarifiers and Trickling Filters

By J. R. SCOVILL
Superintendent, Pearl River Sewer District, Pearl River, N. Y.

This discussion is of necessity confined to preventive maintenance of straight-line clarifiers and trickling filters with rotary distributors.

Originally the Pearl River plant was designed for a daily flow of 0.9 m.g.d., including 0.6 m.g.d. of domestic sewage and 0.3 m.g.d of pretreated industrial waste from the Lederle Laboratories. The final effluent is discharged into the Hackensack River about 10 mi. above the reservoir of the Hackensack Water Company, which serves not only the city of Hackensack, but also many other communities in northern New Jersey. The original flow plan included a grit chamber located in town to protect the lengthy trunk sewer, which includes two inverted siphons, one 1,100 ft. long and one 5,000 ft. long; two primary clarifiers, each 10 ft. wide, 50 ft. long and 10 ft. deep and equipped with straight-line sludge collectors; a dosing chamber with two standard-rate trickling filters 95 ft. in diameter and having 8-ft. depth of stone and rotary distributors; two final clarifiers, 10 ft. wide, 45 ft. long, and 8.5 ft. deep, also equipped with straight-line sludge collectors; a four position sand filter 2.54 acres in area and 3 ft. deep; and effluent chlorination before discharge into the river.

The first major addition was made in 1945 when, because of increased flow from Lederle Laboratories, two additional primary clarifiers 50 ft. long, 12 ft. wide, and 10 ft. deep were added. In 1951-52, because continued high flows and increased strength of the industrial wastes from Lederle Laboratories, it was decided to pump the effluent to the Shanks Village outfall to the Hudson River and to modify the plant to give a design capacity of 1.8 m.g.d., made up of 0.6 m.g.d. of domestic sewage and 1.2 m.g.d. of pretreated industrial wastes with a B.O.D. not to exceed 300 p.p.m. The sand filters were abandoned and a high-rate roughing filter 80 ft. in diameter with stone 8 ft. deep and followed by two secondary clarifiers 64 ft. long, 16 ft. wide, and 8 ft. 3 in. deep was inserted between the primary clarifiers and the standard-rate filters. The final clarifier capacity was doubled by the addition of two final clarifiers of the same dimensions as the originals and equipped with sludge collectors.

Preventive maintenance as practiced at the Pearl River plant consists of the following three parts:

1. Lubrication.
2. Inspection.
3. Parts replacement and painting.

For lubrication it has been found most practical to set up a regular schedule. The system in use at this particular plant is as follows:

Following the manufacturers' recommendations, a schedule was set up for each lubrication point of each piece of equipment throughout the plant. To avoid duplication of lubricants, the industrial lubrication engineer of one manufacturer (in this particular case Tidewater Oil Company) was called in and, using the particular equipment manufacturer's recommendations as to viscosity and pour points, the proper lubricant was selected.

For points which require lubrication one or more times weekly there is a regular weekly schedule with a particular job assigned to each day of the week. The particular schedule in use calls for lubrication of the guide rollers with Asylkeep No. 4 and their tracks with Alastac No. 41 on all rotary distributors, and a check of the oil level in the upper bearing of the high-rate distributor every Monday. On Tuesday all slow-speed bearings on all clarifiers are lubricated, drive chains are painted with Alastac No. 41, and oil levels are checked in all reduction gears.

For points requiring lubrication less often, a 5 in. by 8 in. card index system is used. There are 48 index cards, one for each of the first four weeks in each month. As each week passes, the index card for that week is moved to the rear. There is a card for each point on each piece of equipment. This card shows the piece of equipment, the particular point to be lubricated, the recommended frequency of lubrication and the type of lubricant to be used. When a card comes up in the current week, the point is lubricated or the oil changed, the date is entered on the card, and the card is moved back in the index under the card for the week when the next lubrication is due.

For example, the card for the reduction gears of the No. 1 primary tank came up in the first week in April. It showed that the oil should be changed every four months, in summer with Acobryte No. 91 and in winter with Acobryte No. 83, and that the oil had been changed on December 2 with Acobryte No. 83. The oil was changed on April 3 with Acobryte No. 91, the information was entered on the card, and the card was replaced in the file under the index card for the first week in August.

In this way the card automatically comes up when the point is due for its next lubricating and under-lubrication as well as over-lubrication is avoided.

Inspection and parts replacement also are most important parts of preventive maintenance. Each shift operator as he comes on duty is required to inspect the entire plant with the operator going off duty. Together they check all motor and pump bearings for overheating and generally check all equipment for proper operation.

In addition to this, every three months each clarifier is pumped down, the chains and flights are inspected, the drag chains are tightened if necessary, damaged flights are replaced, and the wearing shoes are checked and replaced when necessary. Once a year the sidewalls from 1 ft. below the water line to 1 ft. above are painted with Inertol Standard Black.

Inspection of the rotary distributors is generally for the purpose of keeping all nozzles clean and in operating condition, keeping the arms level by adjusting the turn buckles on the guy rods or cables, and keeping the guide rollers in proper adjustment. It has been found advisable to take each rotary distributor out of service once a year and to paint all surfaces with Inertol Standard Thick Black.

By following the indicated schedule it is felt that everything possible is being done to prevent major repairs and to keep all equipment in the best possible operating condition.

Spot Test for Sulfides

By P. K. MUELLER and M. C. RAND
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SULFIDES are frequently routinely analyzed in river surveys and in other problems pertaining to water, sewage, and industrial wastes. Many of the samples to be analyzed often show up negative by the quantitative Standard Method[1] of sulfide determination. For these samples much valuable time could be saved if the laborious manipulations of the quantitative determination could be replaced by a sensitive and specific qualitative test for sulfides.

Attention is drawn to Raschig's azide-iodine reaction[2], developed as a spot test for sulfides by Feigl[3,4]. After a thorough investigation of the various procedures for carrying out the test, the following was found to be most suitable from the standpoint of sensitivity and simplicity.

About 1 ml. of the sample is placed in a watch glass on a dark background. About 1 ml. of 30 per cent sodium azide and about 1 ml. of 0.1 N I_2 are added. Bubbles of nitrogen gas will form on the surface of the glass within 2 to 5 min. if sulfides are present.

Using standard sulfide solutions, concentrations of 0.1 p.p.m. and less have been easily detected. In a river survey involving more than 100 sulfide determinations, no sulfides were detected by the standard method when none were detected by the test under discussion. Due to the greater sensitivity of the qualitative method there were a few samples in which sulfides were detected by the azide-iodine reaction, but not by the quantitative method.

Sulfates, sulfites, and elemental sulfur do not interfere, but thiosulfates and thiocyanates give a positive reaction[3,4].

The test is readily applied in the field. This fact enhances its value from the standpoint of collecting and preserving the sample for later analysis in the laboratory. Production and destruction of sulfides may be stopped by addition of 30 p.p.m. mercuric chloride to the sample, without interference in their subsequent determination.

The described test has been used extensively by the authors and has resulted in the elimination of the time-consuming standard quantitative method on samples which give a negative reaction by this qualitative test.

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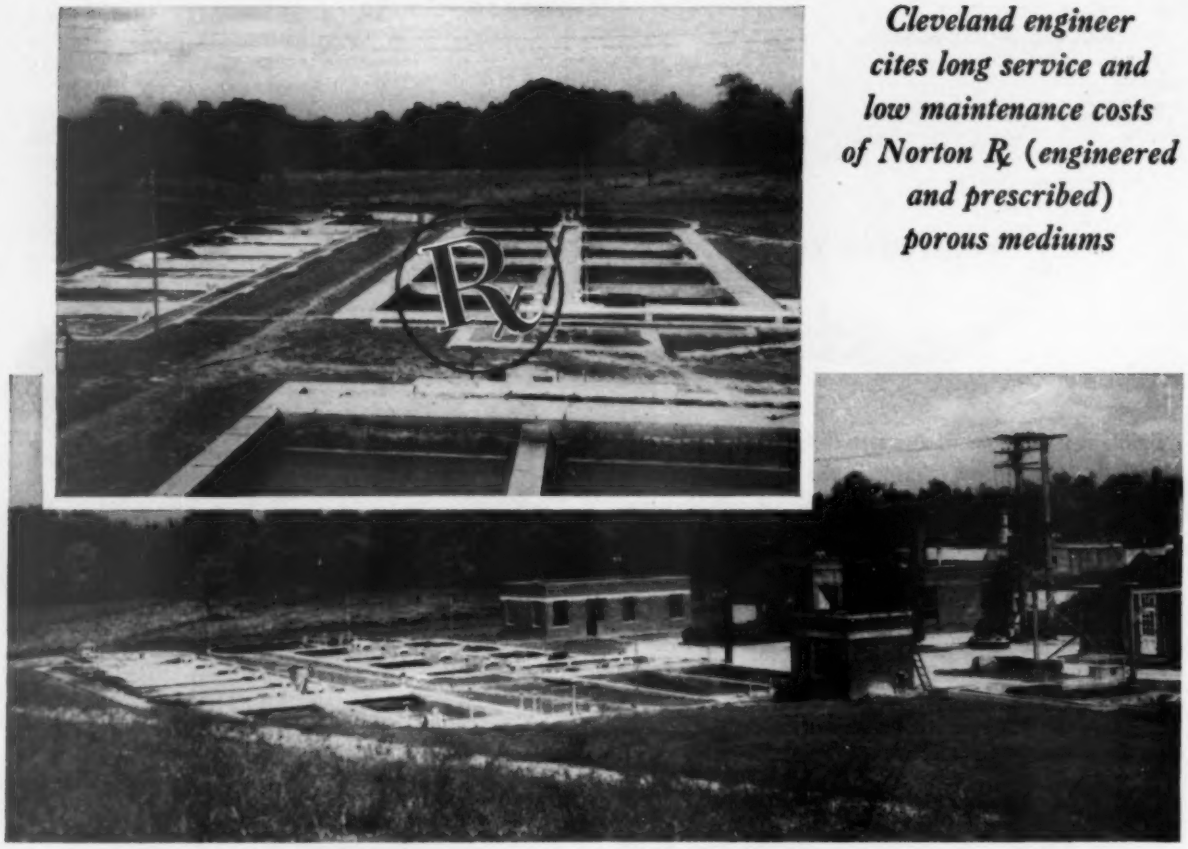

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Activated Sludge Process Operating Fundamentals

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THE properties of activated sludge which are most important to the plant operator are, first, its clarifying or absorptive powers, and, second, its oxidizing power.

When activated sludge is mixed with sewage it absorbs the finely divided suspended matter, the colloids, and probably much material in true solution in or on its floc surfaces. If the sludge is then allowed to settle out, the supernatant liquor will be clear instead of cloudy. This clarification action is very rapid and is probably completed in 10 to 30 minutes.

The oxidizing power of activated sludge is generally assumed to be entirely due to biological action. Although its oxidizing action may be some 60 to 130 times faster than the normal oxidizing rates, as measured by the standard B.O.D. test, it is still much slower than adsorption or clarification.[1] The highest rate of oxidation usually occurs when the sludge first comes in contact with the sewage. It then falls off gradually for the next two to five hours, after which it continues at a more or less uniform rate for considerable periods of time.

In any properly functioning plant there is a balance between these two properties. Almost all of the troubles encountered with the activated sludge process may be traced to a lack of proper balance. For example, if biological oxidation proceeds more rapidly than adsorption, the sludge floc become very small and compact. This dense floc does not produce a sparkling clear effluent although nitrification may be very high. Furthermore, some of the floc is apparently broken up into minute particles which do not settle in the final clarifiers, even though the main body of the sludge settles very rapidly. On the other hand, if oxidation lags behind adsorption, the sludge floc will become so light that it will not settle in the final tanks and the sludge will lose much of its clarifying power. Since adsorption is very rapid and almost automatic, the operator's problem is to regulate the rate of biological oxidation so that it just keeps pace with adsorption under the aeration periods prevailing in his particular plant.

There are several conditions under which oxidation will progress more rapidly than adsorption. Probably the most common is over aeration. It is encountered in plants having excessive blower capacity in a few large constant speed machines. It is best overcome by carrying more sludge in the aeration tanks. A second, but less common, cause of over oxidation is too long an aeration period. The best corrective is to bypass part of the aeration tanks. If that cannot be done, then increase the amount of sludge in the mixed liquor. A third cause of over oxidation may be lack of sufficient "food" in the sewage. The writer encountered such a condition at Grove City during the early spring. At such times our sewage flow is increased by ground water to four or five times its dry weather volume. Most of the excess flow has to be bypassed and hence only one-third to one-fourth as much organic matter enters the aerators as normally. We have found that the admittance (after liming) of digester supernatant to the aerators was quite helpful at that season.

Causes of Oxidation Lag

There are at least six possible causes of oxidation lagging behind adsorption, as follows:

(1) *Inadequate Oxygen Supply:* In any aeration tank (mechanical or diffused air) we have two opposing forces, one, the aerator device injecting air into the mixed liquor, and two, the biological organisms using up oxygen in their life processes. Dissolved oxygen determinations on the mixed liquor give a measure of the excess of the oxygen supply over the oxygen consumption. It is absolutely essential that the rate of supply be at least equal to the rate of consumption, but there is nothing to indicate that any great excess is beneficial.[2] If there is no dissolved oxygen in parts of the aeration tanks then either the oxygen supply must be increased by using more air, or the rate of oxygen consumption must be cut down by reducing the amount of sludge or sewage in the mixed liquor. Naturally sludge reduction is the most general practice.

(2) *Germicidal Wastes:* Since oxidation is entirely biological it is evident that germicidal wastes will stop or retard it. If the germicidal action is due to excessive acidity or alkalinity neutralization with lime or acid will eliminate it. (The optimum pH for biological oxidation is 7.0 to 7.5 although there is little retardation at pH 6.4 to 8.0.[4] If it is due to phenolic compounds or other toxic substances, the only certain remedy is to exclude them from the sewers. In some cases, however, where the concentration of the poison is quite uniform and not too high it may be possible for the sludge organisms to become accustomed to it.

(3) *Excessive Carbon Dioxide:* Carbon dioxide is one of the principal end products of biological oxidation[3,4] and excessive amounts of it are known to be toxic to bacterial activity. Sewage already contains relatively large amounts of CO_2. Although aeration is an efficient means of removing carbon dioxide the rate of its production during the activated sludge process is so great that the net reduction due to aeration may be slight. In such cases it is quite possible that the rate of oxidation is limited by the CO_2 content of the mixed liquor. When such conditions prevail it is logical to apply lime to the inlets of the aeration tanks.[4] Either one of two general schemes may be followed: (a) daily applications of 50 to 300 lbs. of lime per M.G. of daily flow applied in one to four "shots" during hours of peak sewage flow, or (b) continuous lime applications at rates of 300 to 500 ppm. until such time as the pH at the outlet of the aerators approaches 8.0. The best way to tell whether or not excessive CO_2 is causing trouble is to try the lime treatment. It is fortunate that this treatment can do no harm so long as the pH at the outlet of the aerators does not exceed 8.8, whether or not it does any good.

(4) *Septic Sewage or Sludge:* Septic action not only increases the carbon dioxide but produces other products that retard biological oxidation. Avoid sludge accumulations in sewers, channels, primary or final clarifiers. The return of large volumes of poor quality digester overflow liquor to primary tanks may cause the entire sewage flow to become septic. Frequent sewer flushing may be helpful. Prechlorination at various points along the collection system may be even more helpful. Partial chlorination of the return activated sludge has proved beneficial at some plants but chlorine is a powerful germicide and particular care is required to avoid over-chlorination of the sludge which might destroy its oxidizing power.

(5) *Excessive Grease Content of the Sludge:* If the grease content of the sludge is excessive the sludge particles become coated with a film of grease thus preventing intimate contact with oxygen, even though tests show an abundance of dissolved oxygen in the mixed liquor, hence oxidation is greatly retarded. Wiest's[4] work indicates that the activated sludge process functions satisfactorily when the grease content of the sludge is 5 to 7 per cent, but gives considerable trouble when the grease content is around 20 per cent. The writer's experience indicates that 13 per cent grease in the sludge makes for difficult operation while 30 per cent grease causes the sludge to lose its clarifying power and a very inferior effluent results. If the grease content of the sludge is generally excessive then some means of further removing grease from the incoming sewage is indicated. But where the trouble is caused only by periodic shots of mineral oil the writer has found a 25 per cent increase in air for a day following such shots to be helpful.

(6) *Inadequate Aeration Period:* Even under ideal conditions biological oxidation is much slower than adsorption and, hence, there is some minimum aeration period required below which the process will not function. Usually there is nothing the operator can do but bypass part of the sewage flow and ask for more aeration tanks. In some cases, however, short circuiting in diffused air plants has been a factor that could be corrected by proper baffling. Current meter readings at various points may be helpful in designing or locating baffles. In other cases it has been possible to delay major extensions by utilizing part of the aeration tanks for sludge reaeration, thus lengthening the available time for biological oxidation.

Since both the quantity and strength of the sewage varies from hour to hour and day to day, it might be asked, how is the operator to maintain a constant balance between adsorption and oxidation at all times? He can not! In the normal plant oxidation probably falls behind adsorption during the high flow of strong daytime sewage and catches up during the low flow of

weaker night sewage. In some plants it is even possible to observe a gradual deterioration of the sludge through the week with recovery over Sundays. It must always be kept in mind that it is only prolonged periods of excessive adsorption that cause serious sludge deterioration, and that several days of excessive oxidation are required for its recovery. The closer the balance is maintained the lower will be the power costs, but the higher will be the laboratory and attendance costs. Therefore more laboratory work is justified in large plants than in small, but some is required in all.

Sewage Input vs. Air Input, and the D. O. Test

Since most if not all of the oxidation occurs in, or on, the sludge floc, it should be evident that most of the oxygen is consumed by the sludge. Therefore, it is a serious mistake to attempt to regulate the air input in proportion to the sewage flow. Dissolved oxygen determinations throughout the aeration tanks are the best criterion known for air regulation. If the air is to be varied throughout the day then these tests should be made at various hours throughout the day. If a constant rate of aeration is to be used then the tests should be made at whatever time the dissolved oxygen is at a minimum; this will usually be found a few hours *after* receipt of the peak sewage flow. Samples should be collected from various points between the inlet and the outlet of the aerators. Unfortunately the dissolved oxygen determination, the most important of all operating control tests, can not be made directly on the mixed liquor because of interference from the sludge floc. The accurate determination is extremely difficult and requires special equipment,[7] however tests for routine plant control may be made on samples of supernatant liquor siphoned off from larger samples of mixed liquor collected from the aerators. At Salinas, California,[8] the writer collected 2 liter samples from the tanks and allowed them to stand until sufficient clear water could be siphoned off to fill the small D.O. bottles. Ordinarily 5 to 15 minutes standing sufficed although at times of severe bulking as much as 40 minutes was required. That procedure is open to the objection that the sludge consumes some oxygen during the sedimentation period. However, on several occasions we siphoned off a second sample an hour or two after taking the first one and repeated the D.O. determinations; the decrease in dissolved oxygen in the supernatant over the elapsed time was surprisingly small. Theroux, Eldridge and Mallman[9] recommended the addition of 10 ml. of 10 per cent copper sulphate solution to the 2 liter samples of mixed liquor. The copper sulfate acts as a coagulant, speeding up sedimentation, and at the same time halts biological oxygen consumption. Theoretically, at least, this method is open to the objection that the copper sulfate tends to react with the potassium iodide added later liberating iodine and thus giving results that are too high. Heukelekian uses about half as much 10 per cent sulfuric acid in place of the copper sulfate. The writer has tried all three methods simultaneously at Grove City on several occasions and found little or no practical difference. We use copper sulfate in our routine work.

Regardless of the method used to separate out the sludge floc the Rideal-Stewart modification of the Winkler method should always be used for determining the oxygen in the small, siphoned samples because of the possible presence of nitrites in the liquor, see "Standard Methods."[10]

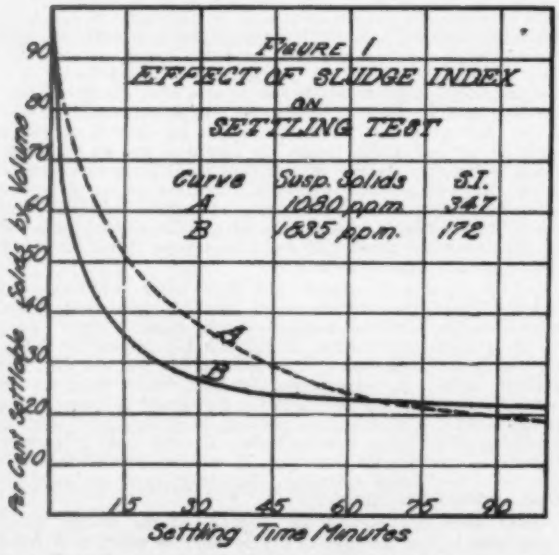

Fig. 1—The Effect of Sludge Density (Sludge Index) on the Volumetric Sludge Settling Test.

Measuring Sludge in Mixed Liquor

We have mentioned increasing or decreasing the amount of sludge in the aerators as a means of controlling the oxydation-adsorption balance. This leads us to the second most important control test, namely, some means of measuring the amount of sludge in the mixed liquor. By amount of sludge we mean *weight* of sludge solids. No universal rule can be given for determining the proper amount. Perhaps 600 to 1500 ppm. of suspended solids in the mixed liquor would cover most mechanical aerators while 1200 to 3000 would cover most compressed air plants. The higher the sludge content of the mixed liquor the faster will adsorption and oxidation progress, but the greater will be the power requirements. If the aeration period is short an increased sludge content will give a higher degree of treatment, but if an adequate aeration period is available almost as good purification can be obtained with a low sludge content and a considerable saving in power may be realized. With a low sludge content organic matter adsorption per unit weight of sludge is very high and hence a very high rate of biological oxidation must be maintained. Therefore, if the sludge content is low, there is more danger of a plant being upset by sudden shots of strong sewage or organic trade wastes.

Standard suspended solids determinations are the only accurate means of finding the actual weight of sludge solids in the mixed liquor. Unfortunately the test requires considerable time and, for small plants, expensive equipment. In spite of these handicaps the test is extremely valuable and should be made at least once a day at all but the very smallest plants. It should be made at the same time each day. The time selected should be such that the sewage flow for the past several hours has been nearly identical with that of the same hours of each preceding day—usually 8 or 9 a.m. will be the most satisfactory time. The writer has followed this practice at Salinas,[8] Topeka[11] and Grove City. We governed the daily amount of activated sludge, wasted almost entirely by the results of these determinations. This procedure does *not* accomplish the very desirable end of keeping the suspended solid content of the aerators constant at all times throughout the day. It was probably a minimum at the time the peak flow started coming in and at a maximum in the evening when the sewage flow drops off. However, it did serve to keep the *average daily* suspended solid content of the aerators fairly constant. If it is desired to hold the solid content of the aerators constant throughout the day then one of the approximate "short-cut" methods of solid determination (to be described later) may be used as frequently as desired, but the standard suspended solids test should be made daily as a check on the short-cut procedure. After considerable experimentation the writer has concluded that the saving in power made possible by hourly checks of the solid content of the aerators was not sufficient to justify the time consumed in checking, but such a conclusion can apply only to the plants with which he was connected. Anderson, employing a centrifugal estimation, has found the opposite to be the case at Rockville Center.[11, 12, 13]

Before leaving the subject of gravimetric solids determinations the writer wishes to make a plea for all operators to base their control on *suspended* solids determinations rather than on *total* solids determinations. It is the suspended solids in the sludge that exert the bulk of its oxygen demand. It would be permissible to base plant control on total solids determinations only if the dissolved solids were practically constant. Such is not the case—at Salinas[8] dissolved solids in the mixed liquor, and plant effluent, ranged from 600 to 1500 ppm. under varying sludge conditions; at Grove City the range is 200 to 500 ppm.

Because of the time required for suspended solids determinations various short-cuts have been used. The simplest are the settling tests and these were the earliest tests used. Samples of sludge or mixed liquor are simply collected in liter graduates, allowed to stand for some given time, and the per cent of settleable solids observed at the end of that time. In the early days it was usually customary to carry a volume of about 20 per cent sludge, after 30 minute standing of the mixed liquor. The test is still used and is quite helpful so long as its limitations are

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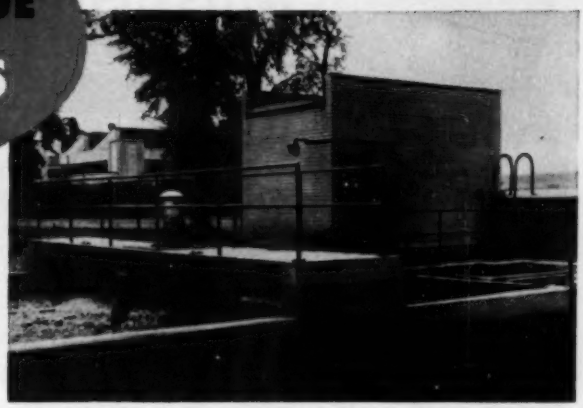

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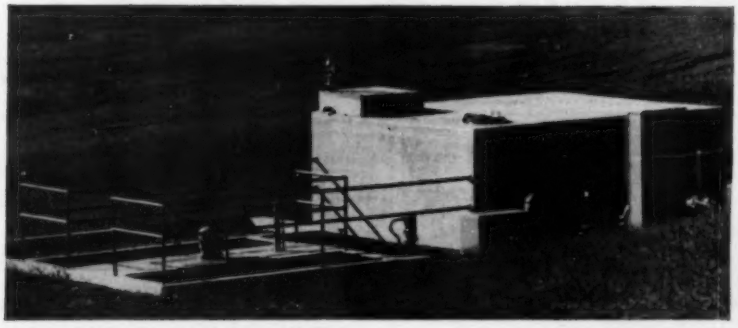

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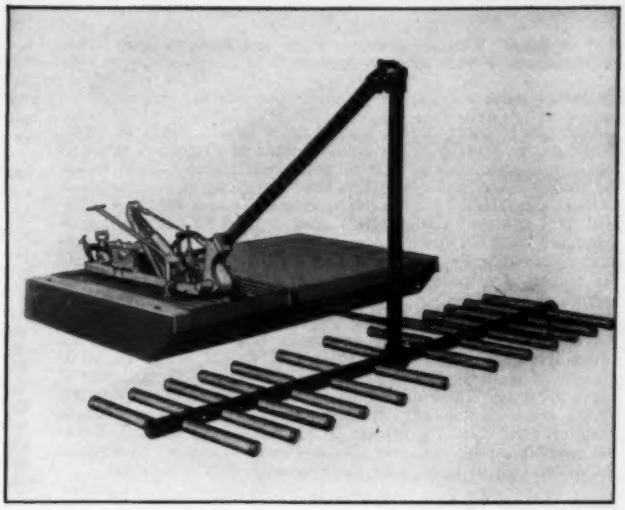

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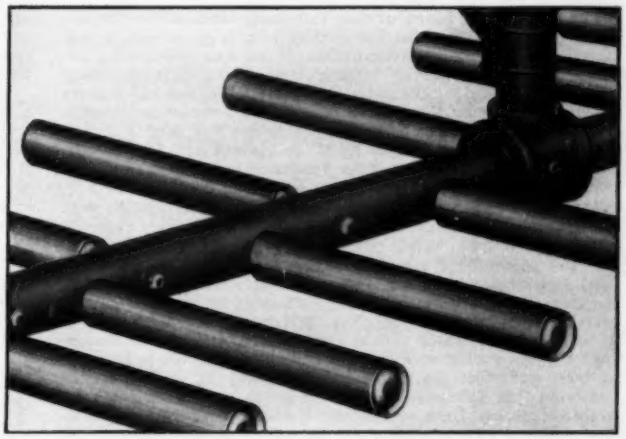

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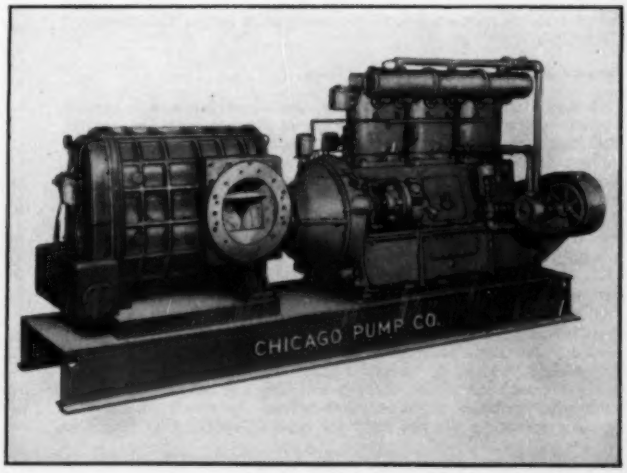

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kept in mind. Various standing times are used, ranging from 10 minutes to 1 hour or even longer.

The Sludge Index

Attempts to correlate the volume of settleable solids, as determined in this way, with the actual weight of suspended solids in the sample soon showed that no such relationship existed unless the sludge index[9] was also taken into consideration, see Figure 2. "The sludge index (S.I.) is the volume in cubic centimeters occupied by 1 gram of sludge solids after settling 30 minutes"; it is computed by multiplying the per cent sludge by volume after 30 minutes standing by 10,000 and dividing that product by the parts per million of suspended solids by weight in the same or a similar sample of mixed liquor. The longer the settling test samples are allowed to stand, i.e., the more the sludge compacts, the less the influence of the S.I. on the results of the test and, hence, the closer their approximation to the actual weight of sludge solids present. Figure 1 illustrates this point fairly well. In general the settling test alone cannot be relied on except in the smallest plants, and even then only in those small plants that are so amply designed that they are subject to little bulking. In such plants the possible saving in power may not be great enough to warrant the added cost of conducting more accurate determinations.

The Centrifuge Test

Another short-cut is the centrifugal test. This test consists of collecting samples of mixed liquor or sludge in 15 ml. centrifuge tubes and "spinning" them for a given short time (2 to 10 minutes) in an electrical centrifuge. A hand centrifuge will not serve because of the impossibility of always spinning the samples at the same speed.

The writer first heard of this test being used at the Indianapolis plant in 1928. Like the settling test, it is, at best, a volumetric determination. Nevertheless, it has two outstanding advantages over the gravity settling test. First, it is extremely rapid, and, second, it compacts the solids more and hence there is better correlation between its results and those of gravimetric suspended solids determinations. The writer has used a 2 minutes spinning period at 2600 r.p.m. at Salinas and Grove City. At both plants we found that the results of this test were greatly influenced by the sludge index, see Figure 3. Setter[10] used a 10 minute period at the same speed and got fair correlation with the suspended solids test so long as the suspended solids exceeded 1000 ppm.; at lower solids concentrations the volume of sediment was too small to permit satisfactory readings. Anderson[10, 11, 12] used a 5 minute period at 1800 r.p.m. at Rockville Center and considers the test very satisfactory although he gives no data to correlate it with suspended solids determinations. If the test is to be used the operator should first make sufficient trials to prepare a graph similar to Figure 3. Once such a graph is available he may determine the sludge index at daily to weekly periods and from that determination and the graph he can select the desirable centrifugal test results for more frequent determinations.

In addition to determining the amount of sludge being carried in the aerators it is desirable to know something of its condition. The sludge index, as previously described, is valuable in this respect. Color, odor, and floc structure are also valuable. Periodic microscopical examinations are useful. After a little experience these tests, or observations, will usually be found adequate for most plants. In some cases the volatile content or dissolved solids content of the sludge may be found helpful.[8] Still better tests required special equipment such as the Odeeometer,[14] Oxy-Utiometer,[15] etc.

Tapered Aeration vs. Delayed Loadings

It was previously stated that the rate of oxidation was usually highest when the sludge first comes in contact with the sewage and that afterwards it falls off gradually. If the air is supplied in just sufficient amounts to maintain a minimum dissolved oxygen content at all points in the tanks it will be found that considerably more air is used at their inlet ends than is used at their outlets. This method is known as *tapered aeration*. Since the rates of adsorption and oxidation increase with increased amounts of sludge, tapered aeration is more necessary when a high sludge content is carried. The rate of oxygenation is limited for any aeration device, but is generally lower for mechanical aerators than for compressed air plants,[17] hence the former usually carry less sludge and frequently provide longer aeration periods. At the Tallman's Island[18] plant provision is made for adding sewage or return sludge at several different points along the aeration tanks, thereby avoiding the necessity of using such high aeration rates at their inlets. In small plants it is possible to reduce the necessity for tapered aeration by returning a large volume of very dilute sludge. Experience has taught many operators that this practice is a good one for small plants in particular. The excess water reduces the oxygen demand of the mixed liquor at the aerator inlets and forces the sludge along the aeration tanks faster, thereby reducing the air requirements at the inlet end and increasing it further along the tanks.

Importance of Prompt Sludge Recirculation

It used to be considered good practice to carry a considerable depth of sludge in the final clarifiers in order to get as high a solid content, and hence as low a volume of return sludge as possible. Studies[19] have shown that the oxygen demand of such sludge is frequently so high that it is almost impossible to satisfy it by any aerating device. It has also been found[20] that the activity of the sludge was greatly impaired by even comparatively short concentration periods in the clarifiers and that the fresher the sludge the greater was its purifying power; the effect being most noticeable at plants having a short aeration period. Therefore, the rate of withdrawal from final tanks should be such as to remove the sludge as quickly as possible. In large plants where the cost of pumping excess water may exceed attendance, or in plants using sludge reaeration, it is wise to make frequent sludge soundings and to keep the rate of withdrawal at a minimum consistent with rapid sludge removal. In small plants that do not have sludge reaeration this extra attendance is not justified and a very high, constant, rate of sludge withdrawal can be used throughout the 24 hours. When the plant is treating a strong sewage the daily sludge withdrawal may be actually equal to the sewage flow with no ill results and, possibly, some benefit. (At first it might appear that such an increase in volume of sludge return would unduly shorten the aeration period; however, it may be shown mathematically that increasing the rate of return from 20 per cent to 50 per cent (equal sludge and sewage volume) cuts the nominal aeration period only 10 per cent because so much of the liquor in consequence passes through the aerators more than once.)

Most plants are not designed for sludge reaeration. If reaeration is used it is desirable to keep the rate of sludge withdrawal from the final tanks at a minimum, consistent with rapid sludge removal, in order to have the longest reaeration period, *providing it is possible to maintain some dissolved oxygen at all points in the reaeration tank.* If that can not be done then the rate of withdrawal *must* be increased so as to reduce the oxygen demand of the reaerating sludge.

Sludge Concentration Important

To intelligently divide the sludge withdrawal between return and waste it is necessary to make daily suspended solids tests on the mixed liquor, as previously discussed. If these results are

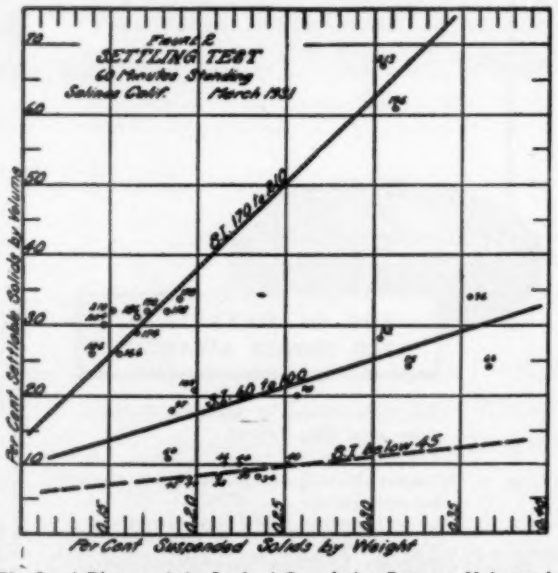

Fig. 2—A Picture of the Lack of Correlation Between Volumetric Sludge Test and the Gravimetric Test. The Necessity of Taking into Consideration the Density and Settleability (Sludge Index) Is Clearly Evident.

below the amount of sludge desired the amount going to waste should be decreased and vice-versa. Waste activated sludge should always be concentrated before introducing it into sludge digestion tanks. At most plants the only means of concentration provided is the introduction of waste activated sludge into the primary settlers. It has been the writer's experience that where this method is used better concentrations of primary sludge are obtained by wasting continuously over the 24 hours at a low rate than are obtained by wasting at a high rate for a shorter time. This method of wasting excess activated sludge has many disadvantages,[21] particularly when the sludge is bulked. A better, though less common method entails the use of a separate tank, termed a sludge thickener, and the use of chlorine.[22, 23] Where a thickener is provided best results are obtained by feeding it with mixed liquor direct from the aeration tanks instead of with sludge withdrawn from the final clarifiers. The clear, chlorinated supernatant from the thickener may be discharged to the incoming raw sewage, the return activated sludge or the final effluent. Either of the first two are preferable because of its beneficial action in overcoming septicity.

Troubles

Now just a few words concerning troubles. Sludge bulking is probably the most common trouble encountered with the activated sludge process. The term "bulking" has been used by some to cover the condition of sludge pouring over the weirs of final clarifiers, but the writer considers that an improper use of the term. A bulked sludge is simply a sludge that, after a given settling period, occupies a greater volume than would a normal sludge containing the same amount of suspended matter by weight. Bulking is best measured by the sludge index[9] as previously described. Whether or not a bulked sludge will pour over the weirs of final clarifiers depends, primarily, upon the design of those tanks. The more generous their design the higher can the sludge index become before the effluent is fouled.

It was previously stated that when oxidation lagged behind adsorption the sludge floc became so light that it would not settle properly, in other words, the sludge bulks. We have given six possible causes of oxidation lagging behind adsorption and suggested means of overcoming them. Any one of those six will cause bulking if not corrected. Certain microscopic, filamentous, growths will cause, or increase, bulking. Sphaerotilus is far the most common organism. Even though the sludge is constantly seeded with these organisms they do not flourish in the sludge if oxidation is keeping pace with adsorption, but if oxidation lags behind adsorption the sludge may become an ideal habitat for profuse growths. Correct the oxidation-adsorption balance and the number of Sphaerotilus will greatly diminish. Other filaments than Sphaerotilus may cause bulking, notably Cladothrix and Leptothrix, but their occurrence is so rare as to warrant no discussion here.

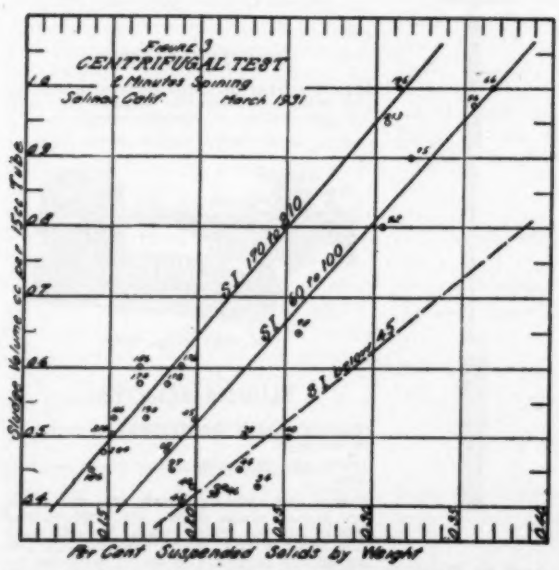

Fig. 3—A Picture of the Less but Evident Effect of Sludge Index Values on Suspended Solids Tests With the Centrifuge.

Bulking is not the only cause of excessive amounts of sludge passing out with the final effluent, although it is the most common one. There are two other causes. One is simply insufficient sludge withdrawal, the other is "sludge rising." Rising sludge is most commonly encountered in plants treating sewage high in nitrogenous matter (notably meat packing wastes) where nitrification is quite high. The sludge will settle rapidly in tanks or graduates, but will rise again in from 20 to 90 minutes. The sludge is lifted by accumulations of nitrogen gas. At some plants[24] it has been overcome by keeping the dissolved oxygen in the aerators very low; at others[25] it has been found helpful to increase the amount of sludge carried in the aerators.

Digester overflow liquor has caused considerable trouble at several activated sludge plants, among them Grove City. At most plants it is common practice to return digester overflow to the raw sewage, and, in a properly proportioned plant, the liquor will cause little or no difficulty providing its solid content does not exceed 0.2 per cent. If the overflow contains more than 0.5 per cent solids it turns primary clarifiers septic and covers them with gas-buoyed sludge. Under such conditions their effluent is very difficult to treat by the activated sludge process. At Grove City we have an overflow averaging well over 1.0 per cent solids. We add lime to it and turn it directly into the aeration tanks. The proper lime dosage, in our case, seems to be about 1 pound of lime to each 10 cubic feet of liquor. The liquor turns the aerators very dark, detracts from the appearance of the effluent, and unquestionably puts a tremendous burden upon the activated sludge process. However, we have been able to treat most of the liquor in this way although it seriously upset the plant when we attempted to return it to the raw sewage.

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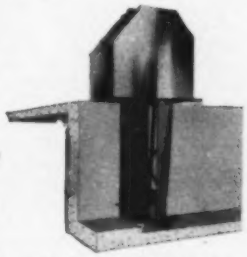

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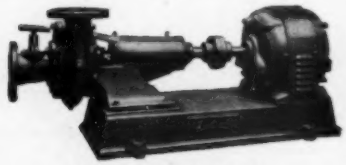

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Waste Water Reclamation and Disposal

By A M RAWN, F. R. BOWERMAN and RALPH STONE

Mr. Rawn is Chief Engr. and Genl. Mgr., and Mr. Bowerman is a San. Engr., Los Angeles County Sanitation Dists., Los Angeles, Calif. Mr. Stone is a Sanitary Engineer with the Univ. of California in Los Angeles, Calif.

THE case for complete divorcement of water reclamation from sewage treatment has been much discussed and well documented[1,2,3]. It has been pointed out, and rightly so, that the success of waste water re-use often depends upon the complete freedom of the water reclamation process from the problems and perplexities which plague sewage treatment plants. But, in propounding the need for separating waste water reclamation from disposal, there lies a danger that the instances in which the two may be integrated will be wholly overlooked. This paper proposes to discuss the circumstances which dictate separation and those which permit the integration of waste water treatment and waste water reclamation (Fig. 1).

The phrase "disposal of waste water" connotes a necessity for appropriate works to: [1] receive all wastes which are tributary to such works, at all times, in such quantities, and containing all of the multitudinous constituents which may enter the collection system; and [2] treat this influent to render it suitable for discharge to a stream, ocean, or lake, or upon the ground, in accordance with accepted health, nuisance, and pollution standards.

The concept of waste water reclamation differs in that the purpose of such a process is to produce a water source suitable for re-use. To achieve this end, it may be necessary to segregate wastes which are susceptible to treatment and re-use, from wastes which would render the final product unusable. In metropolitan areas such as Los Angeles, yielding large quantities of industrial wastes, this requirement clearly dictates a dual system of sewerage to provide adequate ocean disposal for highly mineralized industrial wastes while permitting and re-use of low-mineral industrial and domestic wastes. On the other hand, small towns or cities which are almost exclusively residential are usually free from the problem of highly mineralized effluents, and waste water reclamation is thereby greatly simplified.

The classification of a given project under waste water disposal or waste water reclamation depends on whether the reclamation and re-use of the waste water is merely incidental to the whole scheme of disposal or is planned as an integrated component of the disposal process. Much waste water has been disposed of to the land and to streams, and thereby restored to use, even though there was no reclamation intended; this is termed incidental water reclamation. By contrast, planned water reclamation starts with a predetermined use for the water and, working backward, evolves the optimum process that will provide the quality of effluent necessary. Integrated reclamation of waste water is defined as the combining, planning, and controlling of treatment and reclamation of waste effluents for maximum re-use at minimum cost for treatment.

Where surface water supplies abound, the final disposal of sewage effluents is usually effected by dilution in streams, rivers, or lakes. In the southwestern part of the United States, however, surface waters are virtually nonexistent during the greater portion of the year and final disposal must be made on the land, except in coastal areas. The factors pertaining to successful land disposal of sewage effluents have not been completely understood, but in the last 3 years extensive studies have been made by the Sanitary Engineering Research Project, University of California, both at Los Angeles and at Berkeley, on the fundamental principles of land disposal. Planned water reclamation has lagged because engineering knowledge has been inadequate to enable sanitary engineers to develop land disposal systems logically. The results of the university studies should assist engineers to plan intelligently toward the maximum use of waste waters at the minimum cost for sewage treatment[4].

Economic and Quality Problems

The most common reasons given for not reclaiming waste water is the availability of an inexpensive, adequate supply of raw water. On first thought, this factor might rule out water reclamation in such areas as a feasible enterprise. The criterion should, however, not be simply the cost differential between a natural and a reclaimed water supply. The costs of waste disposal must continue to be borne regardless of the use or non-use of the effluent. In determining reclaimed-water costs, it is reasonable to assume that part or all of the cost of disposal may be assessed against the disposal operation, with only those charges in excess of the disposal cost being assessed against the final water user. The relationship between waste water reclamation costs and those for other water supplies in the Los Angeles metropolitan area is indicated in Table 1.

At Baltimore, the Bethlehem Steel Co. uses the effluents from the Baltimore sewage treatment plant in steel production. The steel company pays only those costs of processing in excess of that required for normal dis-

Table 1
COMPARATIVE COSTS OF RECLAIMED AND OTHER WATER SUPPLIES IN THE LOS ANGELES METROPOLITAN AREA

Type of Sewage Treatment	Cost of Treatment	Possible Uses
Activated sludge process	10-20	industrial cooling and quenching process water fire protection agricultural ground water recharge
Trickling filter process		
Primary sedimentation and oxidation ponds	4-8	industrial cooling and quenching process water fire protecion agricultural ground water recharge
Primary sedimentation	3-5	agricultural (restricted use) ground water recharge

Water Supply	Cost (Before Distribution) $/acre-ft	Possible Uses
Metropolitan Water Dist. (softened Colorado R. water)	25 (minimum)	unrestricted
Los Angeles Dept of Water and Power	17.50 (Owens R. water) 8-12 (local ground water)	unrestricted

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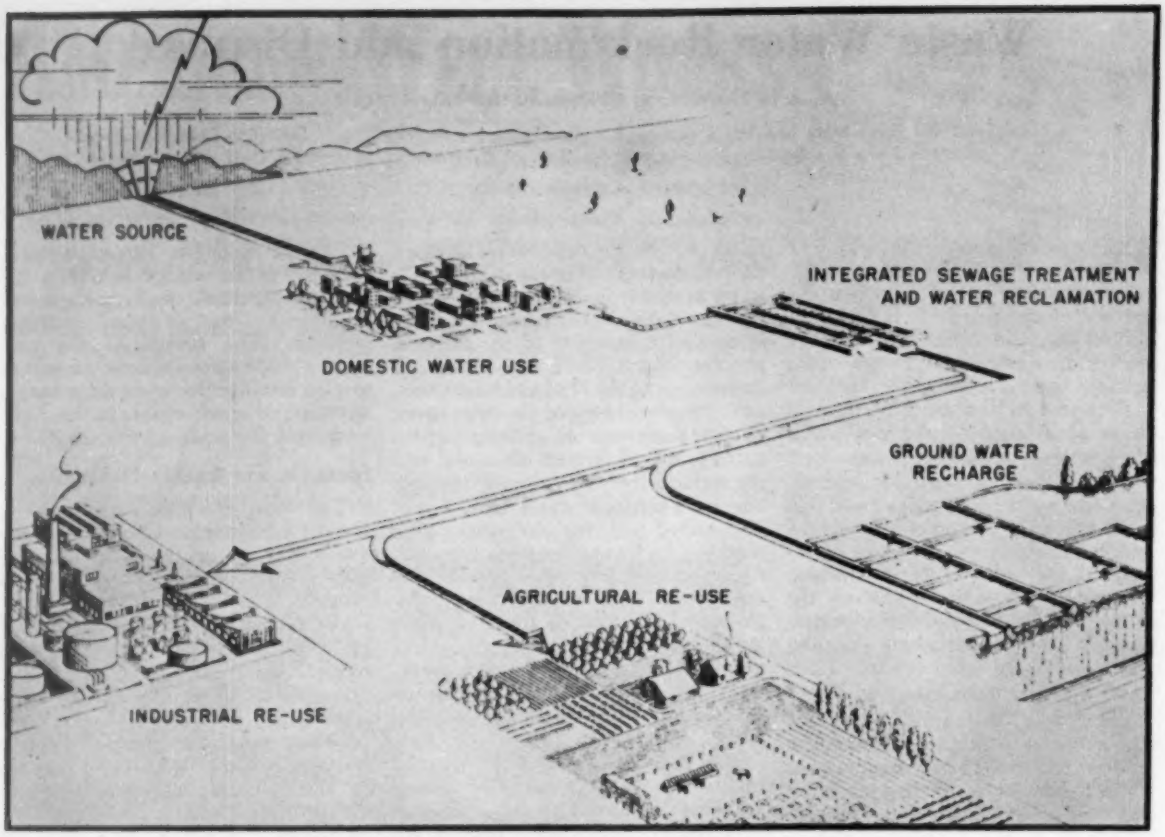

Fig. 1. INTEGRATION of waste water disposal and reclamation.

posal, plus all costs for pumping and distribution to the point of use. In this manner, the cost of the reclaimed water is significantly less than that of other water sources. It seems reasonable to assume that Baltimore should continue to pay those costs which are required for the disposal phase.

Most domestic water supplies are pumped from the ground or taken from surface sources without appreciable concentrations of mineral constituents. Domestic use of water may increase the mineral content by an average of 100-330 ppm of dissolved solids. Industrial use may or may not increase the mineral content; sometimes dissolved solids may increase to as much as several thousand parts per million, raising salinity and hardness so high that any possibility of the re-use of such highly mineralized waters is ruled out (Table 2). Where water supplies are initially high in mineral content, the re-use of waste waters may be less feasible than otherwise.

Health and Public Antipathy

In addition to meeting the tests imposed by economics and mineralization, the re-use of waste waters must meet the tests of health and public antipathy. Health restrictions have been imposed on the re-use of sewage effluents for very good reasons. Domestic sewage contains pathogenic organisms which are potential sources of disease[5]. Broadly speaking, these health considerations prevent the use of reclaimed sewage in any food processing and define certain limitations on agricultural irrigation practices.

Crops which are not utilized directly for domestic consumption or from which there exists no possibility of direct transfer of disease to animals or humans can be irrigated with primary sewage effluents, provided engineering and health principles are observed. Unrestricted crop uses demand well-oxidized, sterilized effluents with essentially the same standards as for potable water. It is apparent that processes involving partial treatment, such as primary sedimentation, will usually result in lower overall costs than would be true for crops irrigated in such a manner as to require an effluent which will meet potable water standards. To prevent the development of a situation in which the final use of an effluent is not commensurate with the degree of treatment, it is good practice to place the supervision of the final use under the same agency that controls the sewage treatment operation.

Table 2
MINERAL CONTENT OF CERTAIN INDUSTRIAL WASTES*

Industry	Hardness ($CaCO_3$) ppm	Chlorides ppm	Dissolved Solids ppm	Alkalinity ($CaCO_3$) ppm	SO_4 ppm
Oil refinery					
Raw-water supply	96	60		266	104
Cooling-tower waste	360	572		56	2,240
Boilerhouse residual and blowdown	87	484	1,424	1,255	
Asphalt processing plant	97	634		400	47
Railroad yard (passenger car and diesel locomotive washings, etc.; after treatment for oil removal)	168	85		122	256
Brewery (bottle-washing waste)			4,000	3,260	
Oil field brines					
Example A (3.5 mgd)		6,000	11,450		22
Example B (3 mgd)		16,400	26,945		0

* Based upon analyses submitted to the Los Angeles County Sanitation Dists. by the industries.

Fig. 2—IRRIGATION of sheep-grazing land with sewage effluent. Fig. 3—Infiltration basin for return of sewage effluent to ground water basin. Fig. 4—Irrigation of citrus grove with paper mill industrial waste.

Public antipathy toward sewage reclamation, whether justified or not, is a very real problem in locating reclamation works. The prejudices against sewage treatment facilities carry over with no loss of intensity to include reclamation plants. Wherever possible, sewage reclamation plants should be located to minimize complaints about possible odors, insects, and other such nuisances. The proper operation of sewage treatment and water reclamation plants depends upon good engineering practices. Experience has clearly shown that such operations can be made acceptable.

Oddly enough, one of the factors which can limit the re-use of waste water in a large metropolitan area is an extensive sewage collection system, which may cover hundreds of square miles and which concentrates large volumes of sewage in areas where limited demand exists. To utilize the reclaimed effluent, it is necessary to transport it to places where it may be used. This may require the construction of separate piping systems to keep reclaimed waste waters from mingling with domestic water supplies. These additional costs, plus the cost for continual pumping, narrow, and sometimes completely eliminate, the margin of economy that exists between reclaimed water and other water supplies. Exceptions exist where metropolitan centers are located upstream from industrial or agricultural water users, but in places where the sewage is collected and treated at a lower elevation it is usually not practical to pump reclaimed waste water upstream to distant areas for reuse.

More desirable would be the location of reclamation plants in various upstream areas, where domestic sources of sewage permit simple treatment, with subsequent discharge at elevations above agricultural or industrial users, who then receive the effluents by gravity flow. Parenthetically, it should be observed that large metropolitan centers usually impose ground water shortages upon themselves because of high industrial and domestic demands. Owing to the high cost of water, caused by scarcity, it is sometimes feasible to go to greater extremes in the reclaiming of waste waters in such areas, where otherwise such proposals would not be considered economical.

Seasonal fluctuations in the demand for water, particularly for agricultural use, impose certain limitations. The mandatory disposal of all collected wastes makes it difficult to integrate the operation with a varying demand for reclaimed waste water. This conflict can be resolved by providing alternative disposal facilities to treat excess quantities of sewage during that portion of the year when irrigation requirements are reduced.

Irrigation and Recharge

In many places, domestic water sources are developed only with considerable difficulty and expense. Agricultural development of land in such areas is uneconomical because of the high cost of irrigation water. Desert areas in the southwestern part of the United States, having alkali soils, can often be reclaimed for agricultural purposes, provided cheap and abundant water supplies can be found. Through planned integration of reclamation and disposal waste waters, a constant supply of relatively inexpensive irrigation water, augmented with significant fertilizer values, may be provided for these water-short areas. This will also hold true for industrial use of reclaimed water in water-short areas that otherwise might not be able to support wet industries.

Where waste water re-use entails spreading-basin infiltration, further economies can be obtained by taking full account of the oxidation which is accomplished in the spreading basin. Effluents discharged to spreading basins require less treatment than if discharged to a small stream or stream bed, as the spreading basin acts as a continuation of the treatment plant oxidation process. The irrigation of orchards or pasture lands ordinarily does not require well-oxidized effluents, and, by integrating the final water use with the degree of sewage treatment needed, the process can be made considerably less expensive than if complete oxidation were achieved in a sewage treatment plant. An example of such integrated reclamation and disposal processes is found at Santa Maria, Calif., where the effluent from a trickling filter sewage treatment plant is utilized in the local high school 4-H project in irrigating crops and pasture for pigs, cows, and other domestic animals. At Fresno and Bakersfield, Calif., city-owned farms are irrigated by primary effluents. At Acton, Calif., the effluent from the trickling filter is used for pasture irrigation at the sheriff's honor farm (Fig. 2), while at Azusa, Calif., the effluent is discharged to spreading basins for return to the ground water (Fig. 3). Many other examples of such installations might be cited (Fig. 4).

It is apparent that integrated reclamation and disposal may be found most feasible in the smaller, isolated cities where there is a concurrence of the following factors: [1] raw water supplies are scarce and expensive; [2] agricultural demand for irrigation water is high; [3] sewage is largely of domestic origin and, hence, of satisfactory mineral quality; [4] sewage treatment can be made simpler and less expensive through the utiliza-

Fig. 5—INTEGRATED reclamation and disposal of waste water. Fig. 6—Ventura, Calif., sewage treatment plant. Fig. 7—Waste water lagoon at a paper mill, the lagoon acting as a recharge basin for ground water infiltration.

tion of reclamation processes which act as a continuation of the oxidation process; and [5] the volume of sewage is relatively small and can be used in areas near the treatment plant.

Ground water recharge and industrial re-use of waste waters may be feasible in metropolitan centers where agricultural re-use is limited. Many industries have learned to re-use process and cooling waters within their own plants, achieving an integration of reclamation and disposal to their economic advantage. The new Lever Brothers plant in Los Angeles is a working illustration of good water reclamation practices which decrease initial raw-water consumption and minimize the quantity of water discharged to sewers. Initial estimates indicated that 20-30 mil gal of water would be wasted daily; through proper engineering design, however, the total discharge from the $25,000,000 plant has been reduced to less than 1 mg. Here is planned water reclamation, integrated into the very heart of the production processes of an industry (Fig. 5). A recent proposal by the Shell Chemical Co. to utilize the flow from the Ventura, Calif., primary sewage treatment plant in the manufacture of ammonium compounds may further demonstrate the possibilities inherent in integrated reclamation and disposal (Fig. 6).

Industrial wastes are not necessarily highly mineralized. On the contrary, many industrial processes increase the mineral content of the water very little. Where such conditions exist, there is an excellent chance to integrate the re-use of such waste into the final disposal process. An example is found at Pomona, Calif., where the Fernstrom Paper Mill has devised a simple, but effective, re-use of the process waters. Recycling and internal re-use of process water finally reaches the point where the wastes must be discharged from the plant for disposal. The wastes are discharged to a lagoon, where part of the water percolates into the soil (Fig. 7) and the rest is subsequently pumped to citrus groves for irrigation. The layer of paper pulp remaining after the water has percolated into the ground is plowed into the soil to become an organic mulch.

Each reclamation proposal must be studied and designed around the factors involved. In such planned projects for integrating the reclamation and disposal of industrial waste water, several benefits can usually be realized: [1] a reduction in the raw-water demand for industrial processing, through internal re-use; [2] a lessened cost for waste treatment, through integration with a re-use process that continues and completes the oxidation; [3] restoration of economic value to the re-used water, equivalent to the cost of obtaining such water elsewhere; and [4] a return of all, or a portion, of the waste to ground water for future withdrawal, in those instances where irrigation or spreading is the final step.

Summary

1. The treatment and disposal of waste water is the processing of liquid wastes to render them suitable for final discharge to streams, oceans, lakes, or ground.

2. Reclamation of waste water connotes the production of water suitable for re-use.

3. Integrated reclamation of waste water is defined as the combining, planning, and controlling of treatment and reclamation of waste effluents for maximum re-use at minimum cost for treatment.

4. Integrated reclamation often depends upon successful land disposal, particularly in the southwestern part of the country. Factors pertaining to land disposal of sewage effluents have not been well understood, but recent studies should assist in future planning.

5. Costs for waste water disposal must continue to be borne regardless of the use or nonuse of the effluent. Charges for the use of a reclaimed water may be employed to reduce costs of disposal, but need not defray the total cost of treatment.

6. Agricultural development of land in water-short areas may be made feasible through the use of inexpensive reclaimed waste waters.

7. Ground water recharge through spreading-basin infiltration should take full account of the oxidation achieved in the spreading basin to reduce the degree and cost of initial treatment.

8. Integrated reclamation and disposal will be found most feasible in smaller, isolated cities where raw water supplies are scarce and expensive, agricultural demand for irrigation water is high, sewage is of proper mineral quality, sewage treatment can be made simpler and less expensive through the utilization of reclamation processes which continue the oxidation process, and the volume of sewage is relatively small and can be used in areas near the treatment plant.

9. High mineralization in some industrial wastes may prevent their reuse; however, many industrial wastes are subject to re-use with simple treatment. Water reclamation in industry should be integrated into the production prodcesses; in this manner industries may materially reduce their demand for raw water and minimize waste disposal requirements.

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Sewer Cleaning With Rubber Beach Balls

By A. M. RAWN
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DURING construction of the sewer lines of the Los Angeles County Sanitation Districts, the problem of cleaning sand and debris from newly constructed lines gave rise to the trial of pneumatic rubber beach balls for this purpose. The use of beach balls was the outgrowth of the usual trial and error methods of using pull through devices, sluicing, use of fire hose and the like.

What is termed a beach ball in this narrative is the ordinary type of commercial pneumatic rubber ball commonly used at play grounds, at beach resorts and otherwise. The rubber is thin and the ball can be blown up to varying degrees of inflation at will. As furnished commercially, the balls have no covering and consist simply of elastic rubber. These balls are manufactured in sizes (diameters) of 6 to 30 inch diameter when fully inflated.

Procedure

For use in cleaning sewers the ball is first inflated and then wrapped in a covering of canvas or burlap, the edges of which are sewed together. A trail-line a little longer than the distance between manholes is then attached securely to the covering. The size of the ball and its covering should be such as to fit fairly snugly into the sewer leaving the downstream side of the manhole.

Immediately the ball is kicked into the pipe, sewage commences to back up in the manhole and continues to increase in depth until such time as its pressure is great enough to force water *under* the ball. (See sketch.) The ball then commences to move downstream through the pipe. Acting as a compressible floating plug it affords enough obstruction so that a continuous high velocity jet spurts under and to some extent around the balls, thereby sluicing all movable material ahead to the next manhole.

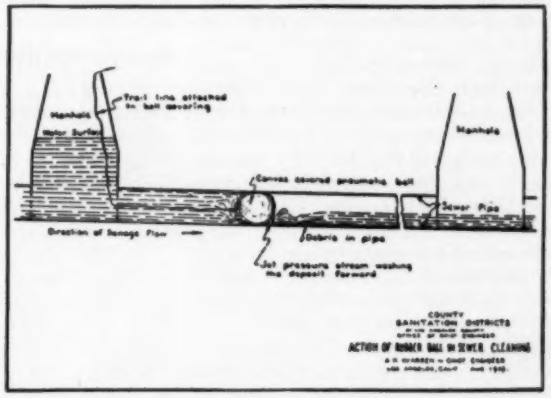
Should the ball encounter an obstruction which is immovable (for instance a joint fin or the like), it merely indents to the necessary degree and moves forward. About the only fixed obstruction which will stop the forward progress of the ball is a root mass or some similar obstruction tightly wedged into the pipe. Brick, stones, bottles, loose metal parts, broken pieces of pipe, sand, gravel and settled sludge are easily moved ahead.

If the ball stops momentarily, a pull on the trail-line is usually sufficient to set it again in motion and if the pipe is quite dirty the trail-line can be snubbed to a step in the upper manhole and the ball's progress retarded to the required degree as the lower manhole is approached, thus giving time for compelte removal of accumulated debris which the sewage has piled up ahead of the ball.

Much time may be saved by conserving the sewage pressure-head as the ball floats into the lower manhole. Just as the ball comes into view at the lower manhole, the snubbed trail-line is cast off and as the ball floats into the lower manhole with the gush of sewage, it is immediately kicked into the lower (outlet) pipe. The trail-line is picked up by fishing for it and the work proceeds as before.

In ordinarily dirty lines three men are employed as a crew and have cleaned in excess of four miles of sewer pipe in an eight hour working day.

The canvas covering serves two purposes: it permits ready attachment of the trail-line and also affords a measure of protection against puncture by razor blades, glass and sharp metal particles in the sewage sediment. The operation and maintenance crew carry along inner tube vulcanizing patches and small holes in balls are readily repaired on the job without much loss of time.



Sketch Showing Action of Beach Ball During Sewer Cleaning

A Real Test

As a measure of the utility of this method of cleaning, one outstanding example will be noted. A 24-inch diameter reinforced concrete pipe inverted siphon carries the sewage of one main under the Los Angeles River flood control channel. The siphon is about 800 feet in length. A ball, with trail-line attached, was inserted in the upstream end of the pipe; and, although, it took thirty-six hours to work its way through, there appeared ahead of it about a truck load of sand, gravel, bricks and boulders as well as a half-dozen flash boards which had dropped into the sewer at the upstream gate.

High-Rate Trickling Filter Performance

Studies of experimental units operated in series and in parallel

By H. HEUKELEKIAN, C. B. McMENAMIN, and M. C. RAND

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THERE are a great number of high-rate trickling filters in existence in this country, and considerable information is available on the operating results, loadings, and efficiencies of such filters. A number of the installations employ double filtration. In some, the primary filter is of the high-rate type, followed by a low-rate filter. In others, both units may be of the high-rate type. Some of the installations practice recirculation; others do not. However, despite the number and variety of high-rate filters upon which data are available, there are few direct comparisons of single-stage filtration with double-stage filtration on the basis of efficiencies at different loadings.

It has been established that two-stage high-rate filters give effluents which compare favorably with standard-rate filters and even with activated sludge. Also, that they are distinctly superior to single-stage high-rate filters. The question raised in this paper, however, does not concern itself with these comparisons, but with the problem of the efficiency of a cubic yard of filter stone in single *vs.* double filtration. The question that is specifically raised is, if two filters are available which can be operated either as single-stage units in parallel or double-stage units in series, which type of treatment would give the highest efficiency with the same sewage and loadings; or, if a new plant were to be built, can the over-all size of the filters be reduced by designing a double filtration type rather than a single filtration and still obtain the desired quality of effluent. It is the purpose of this paper, therefore, to present a comparison of the results obtained in series and parallel operation of a pair of experimental high-rate filters.

The experimental units were set up at the Middlesex Borough sewage treatment plant. The plant is equipped for treatment by sedimentation and chlorination of sewage, augmented during the summer months by chemical coagulation. The dry-weather flow at the plant is 600,000 g.p.d., derived mainly from domestic sources except for 60,000 g.p.d. of waste discharged from a candied fruit manufacturing plant. The waste is high in sugars, B.O.D., and dissolved solids. The discharge of this waste into the municipal sewer increases the B.O.D. of the mixture considerably, making it difficult to obtain a desirable quality of effluent with the primary treatment facilities available, even after chemical coagulation. To meet this situation, secondary treatment of the combined domestic and industrial waste is one of the alternatives. Accordingly, the experimental filters were operated at this plant for two purposes: (1) to obtain the fundamental information mentioned above, and (2) to meet a local situation.

Experimental Apparatus

Figure 1 is a diagram of the experimental equipment, which consists essentially of two trickling filters 15 ft. in diameter and 5 ft. deep, each followed by an upward-flow sedimentation tank. The two units may be operated either in series or in parallel.

Settled sewage from the effluent channel of the primary clarifier of the plant proper is pumped to a constant-head tank, from which the overflow is returned to the primary clarifier. The flow from the constant-head tank to the trickling filters is controlled by valves and orifice discs inserted in the lines to the mixing tanks.

Recirculation is likewise controlled by orifice discs, which regulate the flow from the clarifiers to the mixing tanks.

Sludge from the settling tanks is returned to the primary clarifier of the plant proper.

When the two filters are operated in parallel, settled sewage from the constant-head tank is allowed to flow into both the mixing tanks. The effluent from the filters is lifted to the sedimentation tanks. From each sedimentation tank a portion of the settled effluent, controlled by an orifice disc, is returned to the corresponding mixing tank for recirculation. The overflow from both settling tanks passes to the effluent channel.

For series operation, settled sewage from the constant-head tank is admitted to only one of the mixing tanks. Recirculation is accomplished the same as in parallel operation. However, the overflow from the settling tank following the primary filter is diverted to the mixing tank of the secondary filter. The effluent from the secondary filter passes to the corresponding settling tank, a portion is recirculated to the mixing tank, and the overflow from the settling tank goes to the effluent channel.

Procedure

The filters were operated from May to November during 1947, 1948, 1949, and 1950. The filters were operated in parallel during the first two years, and in series during the last two years. More data were obtained during parallel operation, as each filter during the period was dosed at a different volumetric rate and a different B.O.D. loading. The dosage rates were changed from time to time during both single and double-stage operation periods. Loadings also varied because of fluctuations in the B.O.D. of the applied sewage. Recirculation ratios were also varied from time to time during the entire period of operation.

Once or twice a week samples of the settled sewage and of the influent and effluent of each filter were taken and the 5-day 20° C. B.O.D.'s determined. Each sample so tested was a composite of samples taken hourly from 11 A.M. to 3 P.M., during which time the strength of the sewage applied to the filters was slightly above the daily average, although peak strength did not always occur during those hours. Candied fruit waste was always present in the sewage during the sampling period, which, therefore, represents the most difficult conditions for treatment.

Strength of Sewage Applied

The strength of the sewage applied to the filters was high because of the presence of candied fruit wastes. During the single-stage operation period, the average B.O.D. of 81 samples of applied sewage was 540 p.p.m., with a minimum of 135 p.p.m., and a maximum of 830 p.p.m. During the double-stage operation period, the average B.O.D. of 55 samples of sewage applied was 628 p.p.m., with a minimum of 315 p.p.m. and a maximum of 1,200 p.p.m. The strength of the applied sewage was about 3 to 4 times higher than that of normal domestic

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sewage, and the strength was somewhat less during the period of single-stage operation than during double-stage filtration.

Although the candied fruit waste is deficient in nitrogen, no artificial supplementation was practiced. Since no deficiency was encountered, presumably the mixture of the waste with domestic sewage contained sufficient nitrogen for optimum biological treatment.

Results

The average results of parallel and series operation for the entire period are given in Table I. The volume of applied sewage was 3.8 m.g.a.d. during parallel operation and 3.1 m.g.a.d. during series operation. The recirculation ratio was 3.6 during parallel operation and 6.0 during series operation, including the recirculation in both primary and secondary filters. The total hydraulic load on the filter during parallel operation was 17.5 m.g.a.d., and 21.7 m.g.a.d. during series operation. The B.O.D. of the applied sewage was 540 p.p.m. and 628 p.p.m., respectively, for parallel and series operations. These high B.O.D. values of the settled applied sewage reflect the influence of the candied fruit waste discharged into the municipal sewer. The B.O.D. loads applied during the two periods were nearly alike at 2.5 lb. per cu. yd. per day. However, the effluent during single-stage operation had a B.O.D. of 110 p.p.m., and during parallel operation 39 p.p.m., giving 80 and 89 per cent B.O.D. reductions, respectively, by secondary treatment.

The results are grouped in ranges of B.O.D. loading in Table II for parallel operation, and in Table III for series operation. The recirculation ratios were high for low loadings and decreased with higher loadings. This was not intentional; it would have been more logical either to keep the recirculation ratios constant for different loadings or to increase them with higher loadings. It was, however, dictated by pump capacity, which did not permit higher rates of application of sewage with higher recirculations. It is hoped that in future experiments results will be obtained indicating the effect of different rates of recirculation at critical loadings to determine the minimum recirculation with maximum loadings without deteriorating the quality of the effluent.

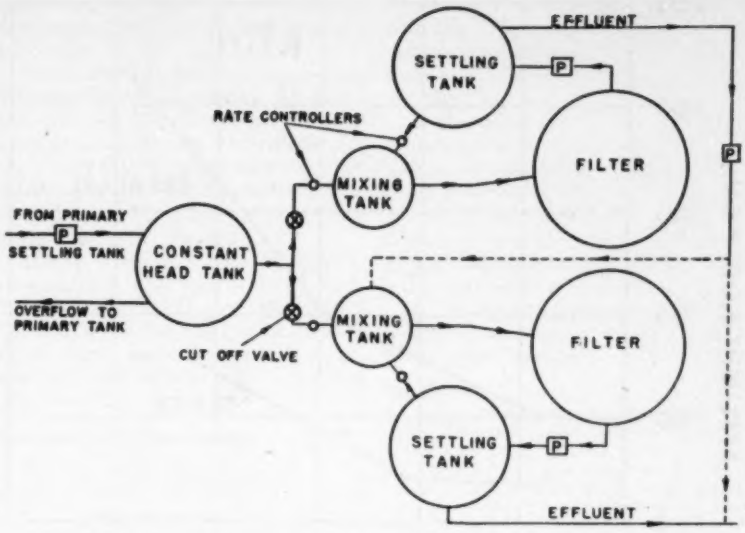

FIGURE 1.—Flow diagram of experimental high-rate trickling filter plant.

Table II

Results of Parallel Operation

Loading (lb. B.O.D.)[1]	No. of Tests	Volume Applied (m.g.a.d.)	Recirc. Ratio	B.O.D. Effl. (p.p.m.)	B.O.D. Red. (%)
1.0	5	2.6	6.1	51	79.5
1.0-1.5	16	1.8	4.8	60	88.2
1.6-2.0	14	2.8	4.5	65	87.4
2.0-2.5	15	3.2	4.4	90	83.5
2.6-3.0	6	4.4	3.6	97	82.2
3.1-3.5	6	6.3	2.3	162	68.7
3.6-4.0	6	5.5	2.2	194	66.1
4.1-4.5	4	5.3	2.2	186	69.5
4.6-5.0	5	6.4	2.2	197	66.5
5.1-6.0	4	6.4	2.0	234	65.4

[1]Pounds B.O.D. per cubic yard per day.

Table II shows that the B.O.D. of the effluent increased quite regularly with increasing loading. The rate of change of effluent B.O.D. is not quite constant, but shows a distinct break at a loading of 3.0 lb. per cubic yard per day. This break is also reflected in the percentage reduction. At loadings of 1 to 3 lb., the removal averages more than 80 per cent. However, when the loading is increased to more than 3 lb. per cubic yard, the reduction drops abruptly to a value of less than 70 per cent, and remains fairly constant in the range from 65 to 70 per cent throughout the range of loadings tested.

Table III shows the results of 2 years' series operation. The loadings are calculated on the basis of the total volume of media in both filters. In series operation, both the effluent B.O.D. and the percentage B.O.D. removal are approximately constant up to a loading of 2.5 lb. per cubic yard per day. Above that loading, the effluent B.O.D. increases, without a material decrease in the percentage reduction.

A comparison between series and parallel operation is shown graphically in Figure 2. It is clear that parallel operation give a higher B.O.D. in the effluent for any given loading. At a loading of 1 lb. per cubic yard per day the effluent from parallel operation has about twice the B.O.D. of the effluent produced by series operation. At a loading of 4 lb. the factor is about 2; but with loadings between 1 and 2.5 lb. the effluent B.O.D. in series operation is about constant, whereas in parallel operation there is a gradual increase of effluent B.O.D. with increasing applied load. At a loading of 2.5 lb. per cubic yard per day, the most efficient point for series operation, the effluent B.O.D. produced by series operation is only one-

Table I

Average Results Obtained During Parallel and Series Operation Periods

Operation	No. of Tests	Volume[1] Applied (m.g.a.d.)	Recirc. Ratio	B.O.D. Applied (p.p.m.)	B.O.D. Applied (lb.)[3]	B.O.D. In Effl. (p.p.m.)	B.O.D. Red. (%)
Parallel	81	3.8	3.6	540	2.6	110	80
Series[2]	55	3.1	6.0	628	2.5	39	89

[1]Volume of untreated waste, excluding recirculation.
[2]Pounds B.O.D. per cubic yard per day.
[3]Volume of sewage and recirculated water and B.O.D. load applied are on the basis of a unit volume of stone in both primary and secondary filters.

Table III

Effect of Increased Loading on the Quality of the Effluent in Series Operation

Loading (lb. B.O.D.)[1]	No. of Tests	Volume Applied (m.g.a.d.)	Recirc. Ratio	B.O.D. Effl. (p.p.m.)	B.O.D. Red. (%)
1.0	2	1.6	10.2	21	96
1.0-1.5	9	2.4	8.3	20	96
1.5-2.0	9	2.5	8.0	19	96
2.0-2.5	8	3.0	5.84	22	96
2.5-3.0	8	3.5	4.7	43	92
3.0-3.5	9	3.7	4.4	42	93
3.5-4.5	8	4.2	5.0	75	88
4.5-5.5	2	4.0	4.0	69	93

[1]Pounds B.O.D. per cubic yard per day.

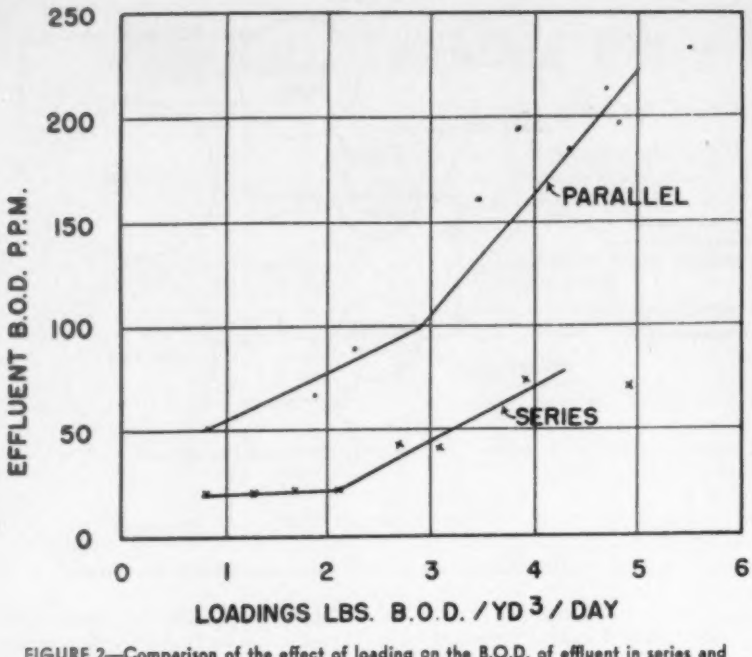

FIGURE 2—Comparison of the effect of loading on the B.O.D. of effluent in series and parallel operations.

third that produced by operating the filters in parallel. Thus, at any loading between 1 and 4 lb. of B.O.D. per cubic yard per day, the effluent B.O.D. from parallel operation averaged 2 to 3 times as high as that produced by series operation.

It follows, from what has been said, that a given effluent standard permits higher loadings in series operation than in parallel operation. For example, an effluent standard of 100 p.p.m. B.O.D. could be met by operating the filters in parallel at a loading of 2.75 lb. per cubic yard, or by operating them in series at a loading of 4.25 lb. On the other hand, an effluent of 20 p.p.m. B.O.D. could be produced by operating the filters in series at a loading of 2.5 lb., whereas no loading in the range tested was low enough to produce consistently an effluent of this quality in parallel operation.

Discussion

The results of this study show that double filtration systems can handle greater B.O.D. loadings and give lower B.O.D. values in the effluent than can be accomplished by single filtration. For instance, with a loading of 2.5 lb. of B.O.D. per cubic yard of stone, a 20-p.p.m. B.O.D. in the effluent could be obtained with double filtration, whereas with the lowest loading obtained with single filtration, 1.0 lb. per cubic yard, the B.O.D. in the effluent was 50 p.p.m. In other words, the efficiency of a cubic yard of stone is at least 2.5 times as great when used in double filtration as it is in single filtration. It should be noted that the loadings given in the double filtration are on the basis of total volume of media in both primary and secondary filters combined. The effluent quality in the loading range from 1 to 2.5 lb. per cubic yard per day is constant at 20 p.p.m. B.O.D. with double filtration. Beyond this range it gradually increases with increasing loading until at about 4.5-lb. loading it reaches 75 p.p.m. The increase in the effluent B.O.D. in the single-stage filtration starts at 1.0-lb. loading and increases gradually until at 4.5-lb. loading it reaches 200 p.p.m. To obtain a 50-p.p.m. B.O.D. in the effluent the B.O.D. loading in the single-stage filtration cannot exceed 1.0 lb. per cubic yard, whereas the same quality of effluent can be obtained with double-stage filtration at a loading rate of 3.0 lb. per cubic yard. The question may be raised as to whether the observed superiority of series operation may not be attributed to the higher over-all recirculations practiced during that period. Although the results do not warrant a positive assertion on this point, it does not seem that an increase in the average recirculation ratio from 3.6 during the parallel operation period to 6.0 during the series operation period could account for the differences obtained because the lower recirculation ratio should prove adequate and increasing the recirculation beyond this should not be of additional value. Furthermore, the total hydraulic loads were 17.5 and 21.7 m.g.a.d., respectively, during parallel and series operation—well beyond the critical flows of 7 to 12 m.g.a.d. A closer analysis reveals that the effluent B.O.D. was 51 p.p.m. during parallel operation with a loading less than 1.0 lb. B.O.D. per cubic yard per day and with a recirculation ratio of 6.1; in series operation a B.O.D. in the effluent of 22 p.p.m. was obtained with 2.0 to 2.5 lb. B.O.D. per cubic yard per day (average, 2.1) and with a recirculation ratio of 5.8. Thus, with nearly equal recirculation ratios better effluents were obtained at more than double the loadings in series operation than in parallel operation. Similar relationships were obtained from results in which nearly equal recirculation ratios are available during the periods of parallel and series operations, as follows:

Recirculation Ratio		Loading (lb. B.O.D./ cu. yd./day)		Effluent B.O.D. (p.p.m.)	
Parallel	Series	Parallel	Series	Parallel	Series
6.1	5.8	1.0	2.1	51	22
4.8	4.7	1.3	2.7	60	43
4.4	4.4	2.2	3.1	90	42

It would, however, be desirable to confirm this point in order to eliminate the possibility of superior performance of series operation arising from the higher recirculation ratios employed.

Information obtained from experiments conducted at Birmingham, England, over a number of years[4,7] with the comparison of single-stage *versus* double-stage filtration with periodic change in the order of filters in series operation, indicates that the volumetric dose on single filters could not be increased beyond 96 gal. (U.S.) per cubic yard per day without impairing the quality. Effluents with comparable quality could be obtained with double alternating filters with rates of application as high as 288 to 300 gal. (U.S.), again a ratio of efficiency 3 times as high as the single-stage filter. True, even these higher rates of volumetric applications on alternating double filtration when translated to loading rates give values of only 0.4 lb. B.O.D. per cubic yard, which is in the upper range of loading of standard filters in the United States. The effiuents in the Birmingham experiments had a B.O.D. of 10 p.p.m. and nitrate-nitrogen of 20 p.p.m., as compared with the 25 p.p.m. B.O.D. obtained in the experiments reported herein with double filtration at a loading value of 2.5 lb. per cubic yard. It is also true that these results in England were accomplished with periodic alternation in the order of filters, otherwise the filters would clog and deteriorate, whereas at no period of the current study, either with single-

stage or double-stage operation, was there any indication of clogging. This may be ascribed to the fact that recirculation was practiced instead of alternation.

A study of two-stage fixed sequence *versus* single-stage biological filtration, both in enclosed artificially ventilated deep filters as reported by Dekema and Krige[2] from South Africa is also of interest in comparison with the results reported herein, despite the obvious differences in the design of filters in the two studies. The authors concluded that 33.8 per cent more flow could be applied and 31 per cent greater removal of B.O.D. accomplished per cubic yard of stone in two-stage filtration than in single-stage with equal purification.

Fischer and Tompson's[3] results dealing with the shallow recirculated filters at Petaluma, Calif., are, on the other hand, somewhat inconclusive in establishing the relative efficiencies of the two types of filters because on the basis of relatively few analyses, the average figures give 110 p.p.m. B.O.D. in the effluent with 5.9 lb. loading per cubic yard per day with single-stage, and 35 p.p.m. B.O.D. in the effluent with 3.1 lb. B.O.D. per cubic yard applied on the two-stage unit. The lower B.O.D. values in the two-stage systems cannot be definitely attributed to double filtration, because they were accomplished with lower loadings than in the single-stage operation.

It is similarly difficult to draw conclusions as to the relative merits of double filtration *vs.* single filtration on the basis of the results obtained at Liberty, N.Y.[1], as the filters here are operated throughout the year in series, except that in winter lower loadings are applied and recirculation is not practiced.

Walton[6] concluded that single-stage filtration gives an over-all 75 to 85 per cent B.O.D. reduction, with an average of less than 80 per cent for the plants studied. For two-stage filtration, the over-all B.O.D. reduction ranged from 85 to 95 per cent, with an average of 90 per cent.

Moore, Smith, and Ruchhoft[5] showed that with nearly equal loadings (2.4 lb. B.O.D. per cubic yard) the B.O.D. in the final effluent from single-stage operation was 31 p.p.m. and that from double-stage operation was 24 p.p.m.

Summary and Conclusions

Two experimental filters 15 ft. in diameter and 5 feet deep were operated for two seasons from May to November on the basis of parallel operation and for two additional seasons on the basis of series operation. Recirculation was practiced. The loadings were varied by (a) changing the flows periodically and (b) fluctuations of B.O.D. in the applied sewage. The sewage contained candied fruit waste containing sugar and high soluble B.O.D. The average B.O.D. of the applied sewage was 540 p.p.m. during single-stage operation and 628 p.p.m. during double filtration. The results based on the B.O.D. of the effluents warrant the following conclusions:

1. The efficiency of the double filtration system was 2.5 to 3 times as high as that of single filtration.

2. A loading of 1 lb. of B.O.D. per cu. yd. per day gave an effluent with a B.O.D. of 50 p.p.m. in single-stage filtration, whereas with double-stage filtration a 20-p.p.m. B.O.D. was obtained in the effluent with a loading as high as 2.5 lb. B.O.D. per cubic yard per day.

3. Between 1 to 2.5 loading range, double filtration gave constant B.O.D. values in the effluent, with higher loads resulting in a gradual increase in B.O.D. of the effluent. In single-stage filtration the B.O.D. in the effluent began to increase with loadings above 1.0 lb. per cubic yard per day.

4. Ponding troubles were not encountered with either system of operation at any loading.

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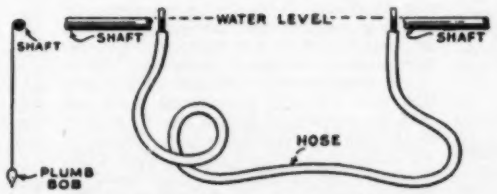
How to Level and Align Shafts by Simple Method



The accompanying sketch shows how to do it. Slip gauge glasses into each end of an ordinary rubber hose and fill with enough water so that the level will show in each glass, as indicated.

When filling the hose with water, care must be exercised to be certain that all air is gotten out of the hose. Hold it in a U-position when filling. Do not attempt to fill it by immersing the hose in a tub of water. Also, one end of the hose must not be warmer than the other end. If the water in one end is warmer it will occupy greater volume and the level will not be true. In other words, get rid of all of the air and use water of the same temperature throughout.

The sketch also shows one of the simplest methods by which shafting can be aligned. Suspend several plumb bobs from the shaft as shown, all from the same side of the shaft. It is then possible to glance along from one end to the other and one can see whether or not the cords supporting the plumb bob are in perfect alignment. If they are not in alignment, the shafting is not straight and should be rectified. A cord stretched lengthwise near the vertical cords enables one to measure the exact amount of misalignment and assist in making the shaft straight.

Sewage Sludge as a Fertilizer

BY A. H. NILES
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NEW operators of sewage plants have often been amazed at the lush growth of garden produce which springs up as volunteer plants around sewage works, many times growing in the partially dried sludge cake undiluted with soil. This observation probably occurred most frequently with tomato plants, which as they grew were much sturdier, much deeper green and much larger than those which happened to grow in the surrounding soil unaffected by sewage sludge.

This new operator probably had only a passing interest in the appearance of these plants but as the season progressed and the fruit began to ripen, the day came when he was perhaps short of sandwiches or was long on appetite. The appearance of a particularly large and luscious looking tomato became irresistible. He had become sufficiently well acclimated to the atmosphere of a sewage treatment works to overcome his natural aversion to the thought of eating a fruit or vegetable which was fertilized directly by human feces, whether fully digested or not.

As this new operator sampled the appealing fruit, he smacked his lips and probably murmured "Hmm—not bad." From that time on he was sold, and being more or less a loquacious individual, did not wish to hide his discovery "under a bushel." He told his friends and they in turn told theirs, so the story of sludge as a fertilizer began to be a matter of not uncommon knowledge. However, as in most cases of this kind, there was considerable misinformation disseminated along with the truth. Soon extravagant claims were made that sewage sludge was the universal panacea for all the ills of the agricultural world. Unscrupulous promoters claimed that sewage plants could be made self-supporting solely by the sale of their sludge as fertilizer.

Farmers long had believed that the only difference between the commercial fertilizer manufacturer and Jesse James was that the commercial product gave no visible evidence of the company having horses, and the salesmen usually did not wear spurs. Soon the commercial fertilizer companies were worried to the point where they were putting out their own brand of propaganda. These statements were that sewage sludge was of such low value that it was not worth hauling home or spreading on the fields even if given to them. Also, that it was full of disease producing bacteria and the user of the produce would certainly contract horrible afflictions or death. As is almost universally the case, the truth, probably, lay somewhere between these two widely divergent viewpoints.

Early Work at Toledo

The writer, being of Welsh extraction, which according to some, is a Scotchman raised to the *n*th power, felt that it was economically wrong to throw away anything of demonstrated value. When the Toledo sewage treatment plant was started, it was decided to give the sludge away for a limited time for advertising purposes. This was all right except for the fact that a few persons obtained sludge which was insufficiently dried. When this was spread upon their lawns and their small children ran across the yard and tracked the sticky mess into the house, their irate mothers promptly consigned the sludge and all persons connected therewith to the place where sludge drying could be most economically accomplished. These unfortunate incidents, together with the psychological fact that, to many persons, anything obtained "for free" has no value, gave the sewage sludge program something of a setback before it really got under way.

A start was made, however, with an attrition mill borrowed from a miller friend. It was not well suited for the purpose but did a passably good job. This was followed by a threshing machine concave and that in turn by a light farm hammer mill primarily suited for grinding grain and feed. Quite a lot of tonnage was put through that old farm mill and the product packaged in used calcium chloride burlap bags obtained from the Street Division. This package was an unattractive one and, besides, its printing indicated that it contained a product to lay dust or melt ice instead of to grow plants. It was sold to the relatively few persons who had previously used the free sludge and were sufficiently pleased with the results to part with real money. This was especially noteworthy because it occurred at a time when pocketbooks were flat—when the CWA leaf-raking program was at its height and national budgets were ending with six zeros instead of nine.

Finally, in 1937, a WPA project was approved to construct a plant to prepare economically the dried sludge for fertilizer and a warehouse to store it in. A contest was initiated in June, 1938, to name the child formally. Many names submitted were not thought usable because of being too expressive, but as a final result, the infant was christened "Tol-e-Gro." It's godfather was rewarded by a handsome prize of 10 bags of the material—a part of which he promptly gave away to his close friends and neighbors.

A multiwall paper bag, printed in two colors, with analyses and complete instructions for use was adopted together with modern equipment for preparing, bagging and handling. A modest newspaper advertising program was inaugurated and a salesman hired for two seasons to get the merchandising campaign under way. Most of this took place in 1938 and 1939. Since that time the oply advertising done has been the printing of folders used by dealers to acquaint their customers with Tol-e-Gro. No salesman has been needed since 1939, for every bit of Tol-e-Gro that could be dried has been sold. In the spring of 1943 at least 250 tons more could have been sold if it had been available.

Just about this time, in the Fall of 1937, the Toledo plant had the good fortune to obtain a chemist who had the background, the training, the energy and the inquisitive mind to do a good job of research. His assignment was to find out what made sewage sludge "tick." It is the purpose of this paper to tell you some of the things he found out.

Fertility Factors in Sludge

First of all, from general observation, it was assumed that sewage sludge had something that promoted growth other than the amounts of nitrogen, phosphoric acid and potash that could be determined from analyses in the chemical laboratory. All that is necessary to confirm this observation is to read the history of China. The Chinese have used their waste products—human, animal and vegetable—for centuries as fertilizers. Their lands are still among the most fertile in the world. Chemical fertilizers were unknown to these uninformed people, yet they maintained the fertility of their land. Their country was too crowded to move to more fertile, virgin fields. It was absolutely essential that they maintain their soil fertility. To do so they used the above mentioned wastes, putting them back into the soil. In Europe, the farmers of today will not tolerate the waste of manures—even human manure is carefully used for fertilizer. These farmers, undoubtedly, knew very little and cared less about how much nitrogen, phosphoric acid and potash were in their wastes. However, they did know that these wastes were what their ground needed to keep it fertile and productive. These manures and natural wastes actually were poor fertilizers if compared analytically with some of the so-called complete fertilizers, such as 4-12-4 or 5-10-10, etc.

It is true that these chemical fertilizers are giving good results. But is it not reasonable to believe that these natural wastes must have something in them or their action which makes them better fertilizers than the straight analysis of nitrogen, phosphoric acid and potash would indicate? No one can make up a standard mix commercial fertilizer with the same analysis as Tol-e-Gro, which is 2.0-2.0-0.30, and come anywhere near to obtaining the results that can be obtained by using Tol-e-Gro or a barnyard manure with a similar analysis. Immediately, it will be said that the organic form of nitrogen is of longer duration and the plant fed more continuously, but that again is not the whole story. The purely chemical analyses in the laboratory do not show the countless billions of little nitrogen-fixation factories found in sewage sludge and manures which take nitrogen from the air and convert it to the form of nitrogenous compounds easily assimilable by the plant life. Tol-e-Gro contains enormous numbers of nitrogen fixation bacteria which are found in some soils in limited quantities but not in all soils. Their presence is conducive to good fertility. These bacteria are collectively known as Azotobacters and Nitrobacters. These micro-organisms have the power of transforming the nitrogen in the air to useful compounds which can be assimilated by plants for food. They not only make nitrogen more available to plant life but they also attack and break down humus, straw, old dead roots and other organic substances in the soil, to useful, life-giving stimulating compounds used by the plant life.

Nitrogen and Nitrate Content

It was found that Tol-e-Gro will increase its nitrogen content by 20 per cent in 7 days if moistened and allowed to stand exposed to air. This nitrogen in the

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Mr. Nile's article is reprinted from Sew. Wks. Jour. by permission.

Ed. Note: Although this articles was prepared about and mentions Tol-e-gro, the sludge from Toledo, Ohio, the information herein is undoubtedly applicable to digested sludge from other sewage plants.

air is changed to ammonia and nitrates which are eagerly taken up by the plants and utilized in their normal metabolism. The Texas Experimental Station Bulletin No. 445 states that similar sewage sludge mixed with samples of different kinds of soils produced from 64 to 134 parts per million of nitrate nitrogen. This is more nitrate nitrogen than is produced in some higher analysis fertilizers. This variation is due largely to the variations of soils rather than to the sewage sludge itself.

Since a medium or normal nitrate soil will show 5 to 15 parts per million, according to Michigan Technical Bulletin No. 132, it is obvious that sewage sludge gives an abundant supply of nitrate nitrogen. Quoting from the above Bulletin No. 132, "The nitrogen of the soil organic matter is transformed to ammonia and then to nitrites and finally to nitrates by means of the action of soil organisms. This process is known as nitrification. In order for a soil to form nitrates naturally, it should have a supply of nitrogen in organic matter, be moist, warm and aerated and have the nitrifying organisms present. Soils low in organic matter are usually low in nitrate and nitrifying organisms. Growing plants obtain most of their nitrogen from the soil as nitrates." Nitrates are water soluble and, unless protected by organic matter, are easily washed through the soil.

Tol-e-Gro supplies an abundance of these nitrifying organisms as well as a good reserve supply of organic matter and prevents leaching of valuable nitrate salts from the soil. The amount of ammonia in the soil is dependent upon the same factors as nitrates, that is, abundance of organic matter and nitrifying organisms. Chemical salts used on soils are easily leached out by heavy rains and partly wasted as far as soil nutrition is concerned.

The use of sewage sludge or manure will, in a large measure, control this leaching as it will hold many times its volume and weight of moisture, thus keeping the dissolved nutrients in contact with roots for a much longer time than would otherwise be possible.

Most sewage sludges have a residual or reserve property of releasing food as the plant needs it. These organisms will make just a certain amount of excess ammonia or nitrate which is more than the plant needs. They cease production of these nutrients and cease their activity until the nitrate concentration falls somewhat. Then the nitrifying bacteria start making more ammonia and nitrate from the air. Thus, there is always available an ample supply of usable nitrogen.

Sewage and sludges and manures are helpful in making heavy clay soils porous and workable. Sandy soils are helped by the humus present in sewage sludge and by the moisture-holding properties of the sludge. Sandy soils are almost always deficient in nitrifying bacteria and certain collodial conditions which are essential to plant growth. Tol-e-Gro supplies the soil with micro-organisms and helps correct these collodial deficiencies.

Chemical Constituents

Many elements are essential to plant growth other than nitrogen, phosphorus and potassium. Many crops have been thoroughly analyzed to find just what elements are needed in their growth. Analyses were made of corn, wheat, sugar beets, alfalfa, tomatoes, barley, rye and cabbage, as reported in *New Agriculture*, April, 1937. The following elements were found to be present in the above crops: nitrogen, phosphorus, potassium, calcium, aluminum, arsenic, barium, beryllium, boron, bromine, chlorine, chromium, cobalt, copper, fluorine, iodine, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, rubidium, silicon, silver, sodium, strontium, sulfur, tin, titanium, vanadium and zinc. This totals 33 elements in all. Of these elements, 22 are present in corn, 26 in wheat, 20 in sugar beets, 27 in alfalfa, 22 in tomatoes, 14 in barley, 15 in rye and 22 in cabbage. Therefore it seems reasonable to assume that a good fertilizer should include more than just nitrogen, phosphate of potash. Tol-e-Gro shows the presence of 29 of these various elements.

Sewage sludge has an abundance of mineral elements, many of which are present in such forms as to be slowly and sufficiently available to plant life. Since about 30 different minerals are being constantly taken from the soil by crops, it seems reasonable that replacement of many of these elements is advisable.

A composite sample of 325 tons of Tol-e-Gro was carefully collected and analyses made of same sample. These analyses are quite complete for all common mineral and non-metallic constituents, and the results, shown in the accompanying table, are expressed in pounds per ton of Tol-e-Gro:

Chemical Constituents of Tol-e-Gro.

Constituent	Pounds per ton
Aluminum	72.0
Arsenic	.2
Barium	1.0
Bismuth	12.0
Boron	+*
Bromine	Tr.**
Calcium	94.8
Ca as limestone	236.8
Chlorine	+*
Chromium	5.0
Cobalt	Tr.**
Copper	16.0
Fluorine	+*
Iodine	Tr.**
Iron	76.0
Lead	15.0
Lithium	Tr.
Magnesium	22.0
Magnesia equivalent	36.5
Molybdenum	Tr.**
Nickel	Tr.**
Nitrogen	42.4
Organic Matter	888.0
Potassium	7.0
Phosphoric Acid	40.3
Selenium	Tr.**
Silicon	146.0
Sodium	+*
Sulfur	65.0
Tin	Tr.**
Zinc	20.0

*Undetermined amounts, but more than a trace.
**Spectrographic analysis confirmed these trace contituents.

It is fitting at this time to take up some of these various elements, showing in some measure just how and why they are vitally important in the metabolism and growth of plants.

Aluminum: Essential to plant growth. It is usually present in soils in sufficient quantity although it may be deficient in sandy soils. Along with the organic matter in the soil, aluminum is active in controlling the collodial functions and water-conserving properties of the soil.

Arsenic: The following statement is taken from *New Agriculture*, April, 1937, issue: "Although formerly believed to be toxic in certain concentrations, it has proven beneficial and stimulates the growth when present in small quantities. As much as 1,000 lbs. per acre have not proven toxic in experimental work." Dr. J. E. Groves of Utah says, "Arsenic stimulates bacterial action in the soil resulting in greater crop yield." He further states: "Arsenic must be applied in enormous amounts before it retards microscopic life." Experiments show that arsenic causes liberation of insoluble elements in the soil, especially phosphate.

Barium: Found in varying amounts in some plants. It is believed to prevent injury from excessive concentrations of other elements. However, there is not much known about the value of barium except that it is found in the structure of some plants, namely, corn, wheat, sugar beets, alfalfa, tomatoes and cabbage.

Boron: Much work has been done on the influence of boron on plant growth in the last 20 years. Warington (1923) and Breachley (1927), at the Rothamsted Experiment Station, believe that boron is essential to plant growth, and this belief is concurred in by Sommer and Lipman (1926), Johnson and Dove (1928) and others in this country. Collins (1927), working at the New Jersey Experimental Station, found that boron did have a stimulating effect when present in small quantities.

Calcium: One of the very essential elements. Non-legume crops will require at least 25 lbs. per acre, while legumes, alfalfa, clover, etc., will require 100 lbs. and more per acre. Most soils, it is true, have calcium in their make-up but it is not always in an easily available form. Calcium, more or less, controls the acid and alkaline balance in the soil. It has a controlling influence on the translocation of sugars and starches in the plant. It is essential to the construction of healthy cell wall of plant tissue.

Chlorine: Apparently useful to plants in small quantities. It seems to have a catalytic effect and tends to make other elements more available.

Copper: Found in many plants and it appears to be essential for sunflowers and tomatoes. Copper gives good results, especially on wet, boggy lands where most minerals have been leached out of the soil. Copper, along with manganese, has decidedly beneficial results with carrots, radishes, beets, cabbage and other garden crops.

Cobalt: In small quantities has been found to stimulate crops. It has been found to be important in tomato, wheat and corn culture (*New Agriculture*, April, 1937).

Magnesium: As essential to plants as phosphorus or potash, yet until recently experimental stations and fertilizer industries have paid little attention to the possibilities of a magnesium hunger or magnesium fertilization. Most plants will show from 5 per cent to 10 per cent magnesium oxide in their ash. Magnesium is a constituent of the chlorophyll molecule. It is absolutely necessary in the production of a healthy green color in plants. Magnesium plays an important role in the translocation of starches in the plant. It is an essential factor in the formation of vegetable fats and oils and functions as a carrier of phosphorus in plant metabolism. Bartholomew (1933) has gained evidence showing that soluble magnesium in plants increases the absorption of phosphorus. Cooper (1930) found that magnesium is desirable for resinous plants. Sewage sludge carries large amounts of easily available magnesium. Loew (1901) showed that for the best development of most common field crops the soil should have a calcium-magnesium ratio of 2 parts of calcium to 1 of magnesium. During wet seasons magnesium is easily leached from the soil. The combination of magnesium with organic material is, therefore, highly desirable as the organic material helps prevent excessive leaching.

Iron: Very essential but most soils contain sufficient amounts for normal growth.

Manganese: A constituent of nearly all field and garden crops. It is now considered to be one of the essential elements for normal growth. McHargue (1926) of the Ken-

tucky Experimental Station demonstrated conclusively that manganese was essential for plant growth. Manganese appears to be necessary in the normal oxidation reactions taking place in plant metabolism. Addition or incorporation of manganese in fertilizers to be used on alkaline soils or soils underlain with lime is important as the alkalinity reduces the availability of manganese. Therefore alkaline soils are apt to be deficient in available manganese. Manganese deficiency is due, largely, to the increasing scarcity of manure. Manure usually contains sufficient manganese for most soils. Sewage sludge contains an abundance of manganese, even more than manures, and is a very good carrier of manganese for fertilizer use.

Sodium: Easily leached from soils and should be replaced. Beets, mangoes, potatoes, wheat, barley and asparagus respond quickly to the presence of sodium salts in the soils. Some experimental stations are using top dressings of sodium chloride, or common salt, with remarkable increases in crops. Sodium seems to help conserve the phorphorus and potash and help the normal reactions in the plant.

Sulfur: Proved to be an essential element to plant growth in 1860. Sulfur is a constituent of many plant proteins, cereals, etc. Sulfur is a constituent of plant flavors and aromatic oils and is a constituent of mustard oil, onions, garlic and many other flavors more pleasant. Many plants require more sulfur than phosphorus (*Commercial Fertilizers*, Collins, 1934).

The annual loss of sulfur through drainage is estimated at between 20 and 50 lbs. per acre. Many plants will respond remarkably to sulfur. Alfalfa will respond to sulfur even better than nitrogenous fertilizers. Cases of alfalfa increases with sulfur-carrying fertilizers have been reported from 50 to 500 per cent. Sulfur increases root growth in most plants (Crocker, 1933). Garden crops such as cabbage, lettuce, radishes, beans, peas, etc., respond readily to sulfur.

Tol-e-Gro contains sulfur bacteria which change insoluble forms of sulfur to soluble sulfates which are available to plants. Tol-e-Gro is rich in sulfur—65 lbs. per ton.

Small amounts of zinc seem to be important to plant life as zinc is found in almost all of the common crop plants and fruits. Zinc controls mottle leaf and rosette in fruit trees.

Other Benefits

Users and experimenters of sewage sludge as fertilizer have repeatedly called attention to the fact that results obtained by using Tol-e-Gro and some similar products are far better than the nitrogen, phosphoric acid and potash analysis would indicate. The importance of other mineral constituents has been shown in a small way. Taking all these minerals into consideration, the results obtained by using Tol-e-Gro are still beyond those expected from the straight, routine, standard analysis.

This may be partially explained on the basis of increased moisture-holding capacity; the change in soil structure, allowing more air to enter and subsequently stimulating oxidation; introduction of large numbers of bacteria to aid decomposition and better balancing of the nitrification processes and flora of the soil.

It has been found in running laboratory comparative tests that the plants grown with Tol-e-Gro had two or three times the root growth of plants grown under identical conditions with commercial 4-12-4 fertilizers. Also, comparative tests with potatoes grown on good loam soil resulted in a 200 per cent increase for hills fertilized with Tol-e-Gro at the rate of 400 lbs. per acre. The root growth was noticeably greater and the potatoes were larger. A search was started to determine in some measure the cause of these fine results and increased root growth. In recent years considerable attention has been focused on the fact that certain organic compounds or chemical substances are able to increase root growth and stem elongation and to influence changes in plant growth. It was in this direction that the search was started.

It is well known that in the presence of nitrifying bacteria, such as Azotobacter Chroococcum, something was formed which induced increased root growth. As previously stated, Tol-e-Gro is virtually alive with nitrifying bacteria. It has been shown that these growth promoting substances are probably not made by the bacteria but are produced as bacteria break down the organic materials upon which they feed. Tol-e-Gro is rich in these organic substances. This explained, in part, the origin of these chemical substances, but the next thing was to demonstrate their presence and approximate the amounts present. These substances were found to be present in small quantities when expressed as pounds per ton, but this is more than sufficient when compared to the requirements for plant stimulation. These substances were identified as derivatives of indole, a complex organic chemical.

Growth Promoting Substances

Dr. Willem Rudolfs, head of research of the New Jersey Agricultural Experiment Station, Dept. of Water and Sewage, together with Messrs. Heineman and Ingols, reported in *Sewage Works Journal*, Vols. 10 and 12, on various growth-promoting substances found in sewage sludge. Their conclusions were that most growth-promoting substances found in sewage sludge were from indole and skatole in the form of indole acetic, indole propionic and indole butyric acids. Tryptophane is also formed by digesting or decomposing sludge. Carotene and ascorbic acid are present in limited quantities.

Many of these substances are soluble and tend to wash or drain out of the digesting sludge. It was found that concentrated filtrate collected from the underdrainage system of the glass-covered sludge drying beds at Toledo was far more potent in growth-promoting substances than the dried sludge. This corroborated the statement heard many times that "the best part of sludge is drained away."

Damoose at Battle Creek, as did Backmeyer at Marion, Ind., found this to be the case when they advocated using, and actually sold on an applied basis, quite large amounts of liquid digested sludge. This method of use certainly has its limitations, but, where possible to handle it economically, it produces wonderful results. For years Hommon, at Canton, O., has disposed of liquid digested sludge directly to a city-owned farm adjacent to the sewage treatment plant, with phenomenal crop yields.

In conclusion, it may be summed up that, measured by purely chemical analyses, sewage sludges do not compare very favorably with many commercial fertilizers. Sewage sludge probably never will drive commercial fertilizer companies out of business. Many of these companies do use sewage sludge as a base and fortify it with additional chemicals to gain the analysis desired. This in part, gains for the commercial fertilizers some of the advantages sewage sludges have.

Even the worst critics of sludge, however, unwillingly perhaps, admit that it has some properties that give plants an "oomph" that a standard commercial fertilizer just does not have.

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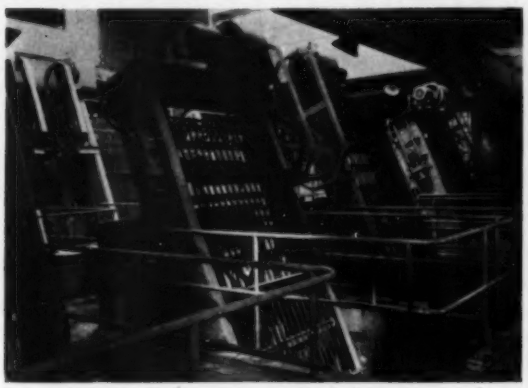
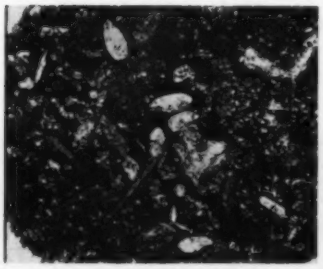
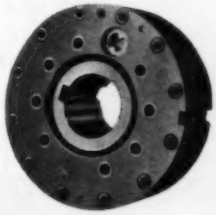


JEFFREY MECHANICALLY CLEANED BAR SCREENS: Above view shows coarse and fine back-cleaned Jeffrey Bar Screens at Owl's Head Sewage Treatment Plant, New York City. Based on new design principle, they are practically foolproof. Time control operations recommended, but operation also can be by differential float. Provision is made for continuous operation if desired. Screen bars may be of round or rectangular cross-section.

JEFFREY "FLOCTROLS": Interior view of FLOCTROL equipped basin at Big Springs, Texas, shows arrangement of paddle wheels and rotating baffles. Jeffrey offers a complete line of equipment for Water, Sewage and Industrial Waste Treatment as well as Biofiltration Systems for purification of sewage and concentrated organic wastes: Bar Screens, Grit Washers (patented), Grit and Sludge Collectors (patented), Sludge Elevators, Screenings and Garbage Grinders (patented), Conveyors, Chains and Bearings.



Raw grit from channel



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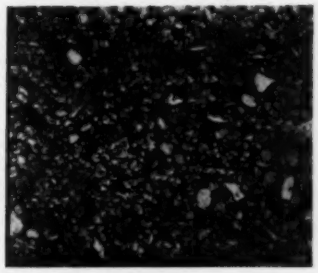

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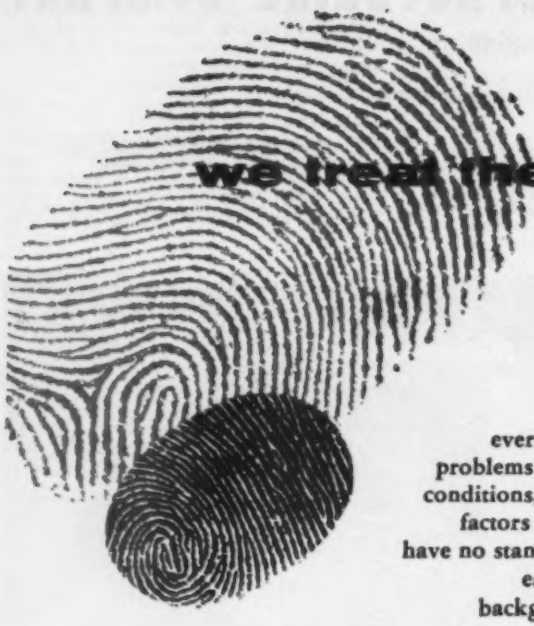

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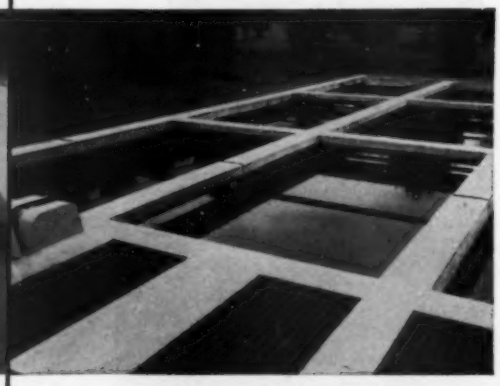

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Sewage Treatment Plant Equipment

By FRANK L. FLOOD

Partner, Metcalf & Eddy, Cons. Engrs., Boston, Mass.

1—Racks, Comminutors, Grinders, Triturators

SOME years ago Dr. Karl Imhoff made a rather extensive tour of United States and Canada inspecting sewage treatment plants. Near the end of this trip he observed to the late Mr. Harrison P. Eddy, that "in America it is fashionable to be mechanical." The trend, as observed by Dr. Imhoff, has continued and developed so that today it is not only fashionable, but practically necessary "to be mechanical" in order to take advantage of advances and developments in sewage treatment methods and processes.

Mechanization of Sewage Treatment

The mechanization of sewage treatment has not been, and is not free of problems which trouble designers, manufacturers, and operators. Initial installations of new processes and equipment are usually accompanied by difficulties necessitating changes, adjustments, and further developments. Even in the case of equipment which has been used for many years, it is desirable occasionally to evaluate experiences and to consider what lessons have been learned and what improvements can be made. It is recognized that the individual experiences may not be general. The characteristics of sewage and of the materials removed therefrom, vary so widely from time to time and from place to place that individual experience with any particular piece of equipment may range from highly satisfactory to unworkable. There is an old saying that "what is one man's food is another man's poison," and another that "the proof of the pudding is in the eating."

However, from the extensive experience with many treatment plants, some general conclusions can be derived which should be helpful to sanitary engineers in their search for the best equipment for any particular service.

The designing engineer's problem is to specify and procure equipment that will perform the desired services in a satisfactory manner for a reasonable life and involve a minimum of maintenance and operating expense. The manufacturers, without doubt, have similar aims, but they are in general in a highly competitive field, and unless the plans and specifications are clear and specific, the client may not always obtain the best equipment for the particular service. Much equipment in the sewage works field is subjected to abrasive and corrosive conditions. Equipment must be sturdy and careful attention given to choice of materials or to painting and protective coatings. Ready replacement of parts subjected to wear should be provided for. Equipment which does not satisfactorily perform the service for which it was provided causes headaches to the operators and reflects unfavorably upon the designing engineers and the manufacturers.

Sewage plant mechanization places certain responsibilities on the authority served. The necessary personnel and funds for maintenance, operation, renewals and repairs must be provided. The personnel must be capable and willing to make the equipment function in accordance with its purpose. A great deal of expensive equipment at sewage treatment plants may be seen lying idle, serving no useful purpose and deteriorating from lack of the necessary funds or the will or the know-how to make it work. Some of this idle equipment was possibly not suitable in the first place, but much of it could be operating successfully with proper care.

Racks

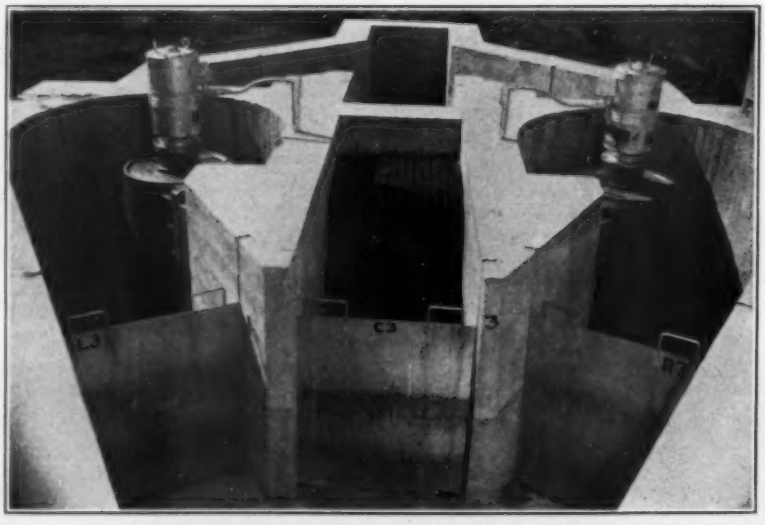
The operation of mechanically cleaned racks has frequently been accompanied by excessive wear on moving parts, stalling of the rakes, failure of float-operating controls to function, excessive corrosion of rakes and bars and other difficulties with resultant excessive repair and maintenance costs. Improvements and refinements in design make it possible to eliminate some of these troubles.

The difficulties encountered in the operation of large mechanically cleaned racks within the Chicago Sanitary District, have been given considerable study and analysis. The fundamental principle of design which greatly reduces the cost of maintenance and repairs as reported by L. M. Johnson[1] may be summarized as follows:

1. All parts should be designed to carry any loads required of them.
2. Motors should be selected within the maximum safe stresses of all parts.
3. Removable mild steel wearing strips should be provided on chain guides.
4. The rack mechanism should be pivoted at the floor line so that it can be lifted out of the flow in the event of a jammed rake.
5. The chains should be of heat-treated malleable iron.
6. The sprocket teeth should be chilled to produce extremely hard wearing surfaces.
7. Wide wearing shoes should be provided on the chain side bars.
8. The rake teeth should be of high bending strength and readily replaceable.
9. The rakes should be operated intermittently by time switches.

The city of New York accepted a design of mechanical rack-cleaning equipment for the Manhattan grit chambers in which the teeth entered the screen bars against the

(1) Municipal Sanitation, August 1938, page 391.

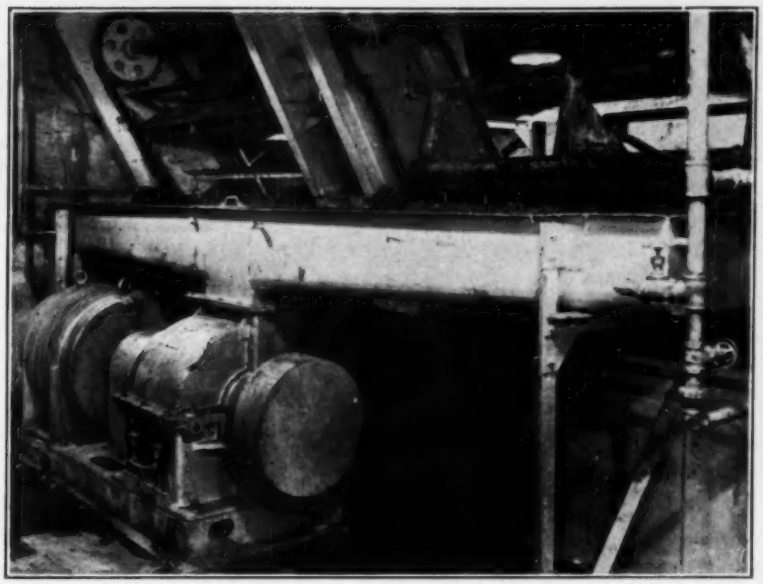


Bristol, Conn.—Bypass Rack and Chicago Pump Co. Comminutors

flow at the bottom. Thence the rake moves in an upward direction with the teeth protruding between the bars out on the face of the rack carrying screenings along the bars and over the top. The rakings fall off as the rakes disengage the screen bars. The results of operation of this installation at the Manhattan grit chambers were so satisfactory that the city of New York has, we believe, settled upon this type of rack for subsequent installations.

After a thorough investigation of the operation of the racks at the Manhattan grit chamber, Mr. Karl R. Kennison, Chief Engineer, Construction Division, Boston Metropolitan District Commission, adopted this type of rack with some modifications for the racks at the Nut Island plant in the Boston South Metropolitan Sewerage District. This type of rack has also been adopted for installation ahead of the main sewage pumps at the Toronto Ashbridges Bay sewage treatment plant.

For a while, it appeared that comminutors possibly would displace mechanically cleaned racks generally as the first step in treatment at sewage treatment plants for all except very small and very large plants. However, it has developed that comminutors may advantageously be preceded by grit chambers in order to reduce the cost of replacement of worn parts. Grit chambers are now almost universally required at sewage treatment plants regardless of whether or not the sewerage system is on the separate or the combined plan. In most instances, such grit chambers, particularly where equipped with mechanical grit-removal mechanisms should be preceded by coarse or medium racks. Thus it would appear that mechanically cleaned racks will still be required for many sizeable sewage treatment plants in the future.



Screenings Grinder—Jeffrey Mfg. Co.

Operation Control

Experience has indicated that the maintenance work required on racks is substantially in proportion to the hours of operation. Consequently controls have been developed to assure that the racks will be operated intermittently as needed.

Common methods of control include time clocks and floats operating on either high-water level in part of the rack or the differential water level in front of and following the rack.

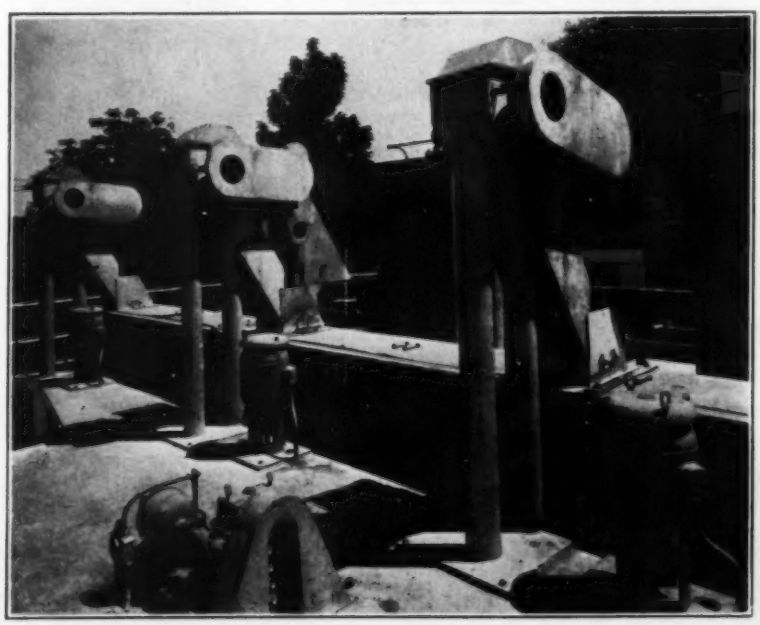
The clocks can be set to operate the racks intermittently. To eliminate possible overload on the rack between periods of operation, it is customary to set the operating time interval so as to take care of the maximum rate of accumulation of materials on the rack. Obviously, for much of the time, the rack operates more frequently than is required, resulting in unnecessary wear on the mechanism and on the controls.

The clock controls involve less installation cost than float or air controls and are not subjected to the difficulties encountered with float controls.

Some authorities require that all mechanical rack operating units, normally operated by timing devices, be provided with auxiliary float controls which will set the raking mechanism in operation at predetermined high-water marks independently of the timed control.

The use of float controls has been troublesome at some installations because of solids accumulating on the floats and on suspension cords and because of their corrosion in the rack channels. The condition as regards the accumulation of materials on floats has been corrected in part at least, by providing float wells adjacent to the rack channels and connected thereto. A small quantity of flushing water creating a flow from the float wells into the rack channels can be provided to keep the float wells reasonably fresh and free of sewage solids. Corrosion can be overcome for the most part by careful selection of materials of construction.

To eliminate the difficulties encountered with float controls, a system of controls which rely on differential air pressure in pipes, immersed in the sewage in front of and behind the rack has been developed. This system is reported to give very satisfactory results. A small amount of air is necessary to activate the controls.



Decatur, Ill.—Screenings and Grit Separators Mechanisms by Walker Process Equipment Co.

Rakings

The materials removed by racks are offensive to sight and smell. It is desirable to dispose of them promptly with a minimum of handling. Much of the material removed by racks can be disposed of with the other sewage solids after grinding or comminution. Pieces of metal and sizeable chunks of wood should be removed from the rakings and disposed of separately. The common methods of preparing the solids returnable to the sewage flow, are by comminutors, grinders, and triturators. At the Los Angeles Hyperion plant, the rakings removed by the racks ahead of the Dorr detritors will be treated by an installation

CHICAGO SEWAGE EQUIPMENT

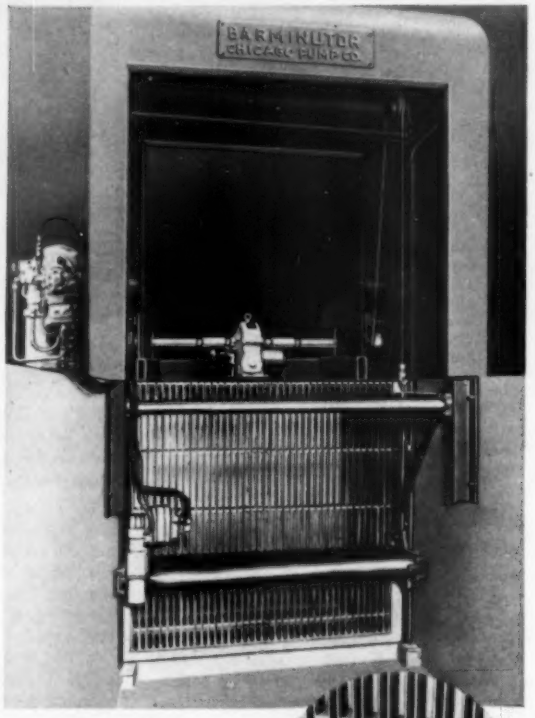
BARMINUTOR*

A New Comminution Development

ORIGINATORS OF THE ONLY SUCCESSFUL EQUIPMENT FOR

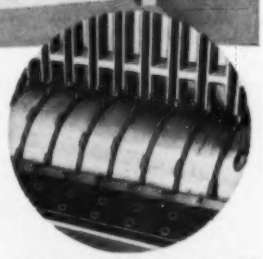
The Barminutor Model "A" exclusively provides all the advantages of comminution with maximum economy for flows from 10 M.G.D. Screening and cutting of coarse sewage material is accomplished without removal from the flow, maintaining continuous cleaning of the screen. The Barminutor, developed and tested over five years, based on nineteen years successful experience with the Comminutor, eliminates odors and handling nuisance in the screening process. High rate cutting in the flow—comminution—provides lowest maintenance cost and long life for cutting parts.

In tests conducted on a Barminutor installed at the Indianapolis, Indiana Sewage Treatment Plant, the unit was subjected to test loads of screenings up to six times normal load for 40 M.G.D. This material was comminuted in six minutes. Even with this heavy load, head loss through the screen did not exceed 6". Like the Comminutor, power requirements are low.



Barminutor installed in 5′ channel.

**Chicago Pump Company's trade name for its new screening and comminuting device for large sewage flows from 10 M.G.D.*



Close-up of Cutters and Combs. Cutters rotate within slots of Bar and Comb.

FUNCTION OF THE BARMINUTOR

1. Cleaning the ¾" vertical bar screen and cutting of the screenings is accomplished by continual travel of the comminuting unit at 8 ft. per minute. Both upward and downward travel is controlled by an electric reversing brake motor.

2. The cutters on the comminuting unit, rotating at 400 R.P.M., travel within slots of the U-shaped bars and carry coarse material to the combs for cutting.

3. The direction of rotation automatically reverses when the direction of travel changes. The combs automatically position themselves to accomplish rapid cutting for each direction of rotation.

4. Uncuttable material is automatically rejected without damage to the cutting parts.

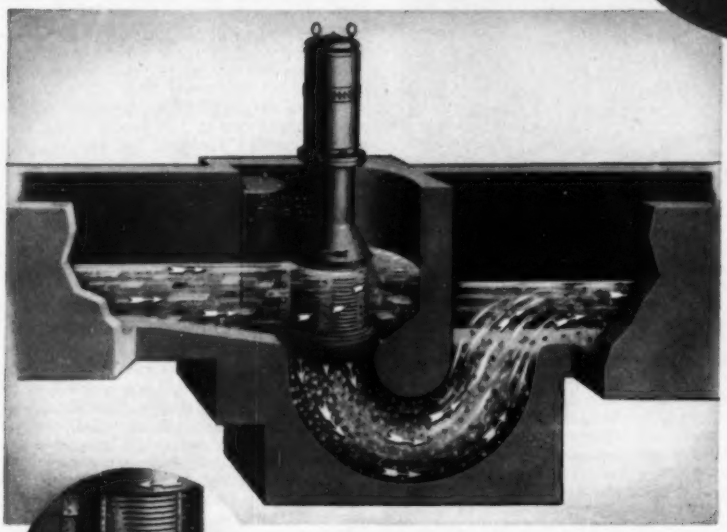
5. Rotation of cutters, position of combs and rejection of uncuttable material is accomplished through an oil powered hydraulic system.

COMMINUTION

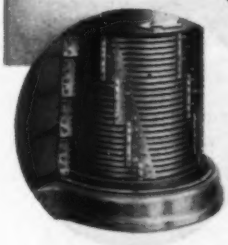
CHICAGO SEWAGE EQUIPMENT

COMMINUTOR

More than 2,500 Successful Installations



Comminutor installed in a basin forming a part of the raw sewage channel.



A full view of the slotted drum, comb, shearing bars and cutters, showing the relation of the various parts that do the cutting.

Chicago Pump Company developed and perfected the comminution process. The Comminutor and Barminutor alone meet all the requirements that 19 years experience show are necessary for successful operation. The Comminutor provides a clean odorless automatic method of disposing of coarse sewage matter. All coarse material is cut into small settleable solids without removal from the channel. The Comminutor is especially adaptable to plants with flows up to 15 M.G.D., but larger flows are frequently handled with multiple channels. For flows above 15 M.G.D., the Barminutor provides all the advantages of the Comminutor.

ADVANTAGES OF COMMINUTION

1. Comminution provides continuous and automatic screening and cutting of coarse sewage matter into small, settleable solids without removal from the sewage channel, thus eliminating odors, flies, unsightliness and clogging of piping and mechanical equipment.

2. Comminuted matter completely settles out in the primary settling tank and is pumped into the digester with the raw sludge. In the case of disposal into bodies of water the comminuted solids settle rapidly, thus preventing shoaling of unsightly matter on beaches, shores or banks.

3. Comminution—clean, odorless and automatic disposal of coarse sewage matter — eliminates the necessity of manually or mechanically raking screenings for disposal by hauling, burial, incineration or feeding to a grinding mechanism.

4. Manual attention required only for periodic inspection, cutter sharpening and lubrication.

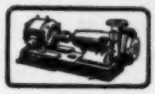
5. Power requirement is negligible—the inertia effect of the drum does the cutting.

CHICAGO PUMP COMPANY

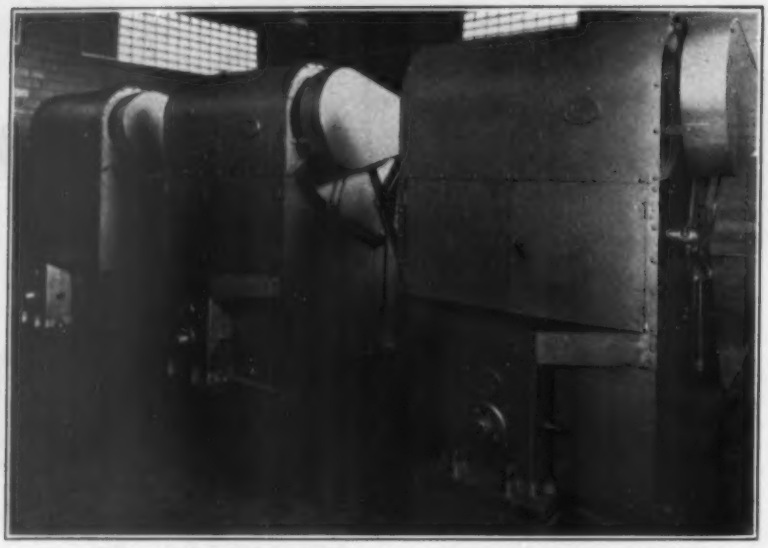
SEWAGE EQUIPMENT DIVISION

622 DIVERSEY PARKWAY — **CHICAGO 14, ILLINOIS**

Flush Kleen, Scru-Peller, Plunger. Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers.



Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.



Denver, Colo.—Automatically Cleaned Bar Screens and Chain Belt Screenings Triturator

of Chicago comminutors. At the Toronto Ashbridges Bay plant, each of 6 racks will be equipped with a Jeffrey grinder. The rakings will be discharged onto a sorting table and manually fed to the grinders after materials not suitable for grinding or return to sewage flow have been removed.

At Baltimore, there are a number of installations at which the rakings at each rack discharge to a short belt conveyor. These rakings are thence carried to a separate grinder for each rack and are comminuted. Keefer reports that these installations work automatically without the necessity for manual removal of metallic and bulky materials. The evidence at several other plants is that it is not safe to rely upon automatic operation for feeding rakings to the grinders.

Comminutors

For purposes of discussion the word comminutor will be used to denote mechanisms which intercept and cut up coarse sewage solids while still immersed in the sewage flow. Until recently the Chicago Pump Co. comminutors have had competition in this field primarily from a combination of mechanically cleaned rack and grinder or triturator. The Worthington comminutor has been introduced recently and other machines for cutting up solids in the sewage flow have been, or are being, developed.

Essex Fells, N.J.—Worthington's Comminutor

While the teeth, comb and drum of the Chicago comminutor have been made of tough, wear-resisting metal, experience has shown that the wear is considerable, particularly on combined systems, unless the comminutors are preceded by grit channels. The Chicago Pump Co. has made recommendations for location of comminutor in respect to grit chambers as follows:

"Where grit chambers are required to remove heavy grit from combined sewage or gravel from street-wash, it is preferable to locate the comminutors downstream from grit chambers.

"Where it is not feasible to locate comminutors downstream from grit chambers due to structural difficulties, or to the possibility of clogging mechanical grit-removal mechanisms by uncut rags, special precaution should be taken to make the comminutor basin as accessible as possible for periodic removal of grit by the operator, to prevent undue accumulations."

Where grit chambers are required but conditions do not make it advisable to install mechanical grit-removal equipment, the comminutors usually can be conveniently located following the grit channels. Where mechanical grit-removal equipment is provided and comminutors are located ahead of the grit channels, then not only must the special precautions noted by the Chicago Pump Co. be followed but it should be recognized by the designer, operator, and owner that the necessary labor and expense must be provided to maintain reasonably sharp teeth to maintain reasonably sharp teeth and to replace worn parts as required.

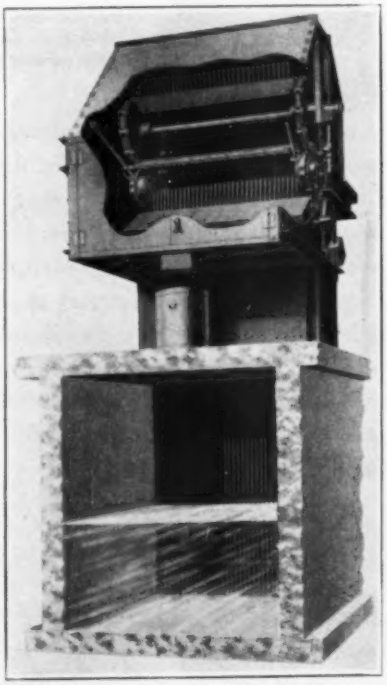
At the Nut Island plant, Boston, it was deemed advisable to install mechanically cleaned coarse bar racks ahead of the mechanically cleaned grit channels and to provide comminutors to handle the normal dry-weather flow at the effluent end of the grit channels. Supplementary mechanically cleaned fine screens were provided at the effluent end of the grit channels to treat storm flows in excess of normal maximum dry-weather rates. The screenings removed by both the coarse and fine racks will be returned to the sewage flow ahead of the comminutors. The comminutors were supplied by the Chicago Pump Co. and the rack equipment by the Jeffrey Manufacturing Co.

Grinders and Triturators

Machines for cutting up sewage solids are removed by racks and screens, out of the sewage flow, are available in two main types, the grinder as manufactured by Jeffrey and by Gruendler and the triturator as manufactured by the Chain Belt Company. The grinder is designed to grind the screenings between a high-speed rotor equipped with swing hammers, and a serrated shredder plate. The swing hammers are commonly made of high-carbon steel hardened and tempered, made easily removable and capable of being shifted end to end and side to side so as to give four wearing edges. The shredder bar assembly is also usually made of high-carbon steel, hardened and tempered, and with easily replaceable bars.

The triturator at one time consisted essentially of a toothed rotor revolving at high speed between two grates, the cutting teeth intermeshing the grate bars. As presently described, the toothed rotor operates against a perforated screen for positive extrusion of the rakings through the screen holes and simultaneous shear cutting by the teeth against the screen.

At Buffalo, N.Y., the screenings from the fine racks were passed through triturators for the first six years of operation at the Birds Island plant. For the past four years, however, the screenings have been disposed of by burial after the operators reached the conclusion that handling, transporting and burial presented less of a problem than grinding. At this plant, it was found that the screenings contained so much hard material, such as bits of stone and pieces of metal and wood, that the effective life of the teeth was very short. New or resharpened teeth became dull in a very few hours of operation and then did not properly shred the material passed through them. This gave a great deal of trouble further along because of the condition in which the rags were left.



Thru-Clean Bar Screen by Link-Belt Co.

Both grinders and triturators have been in successful operation for at least ten years in moderate-sized sewage treatment plants with which we have been associated as engineers.

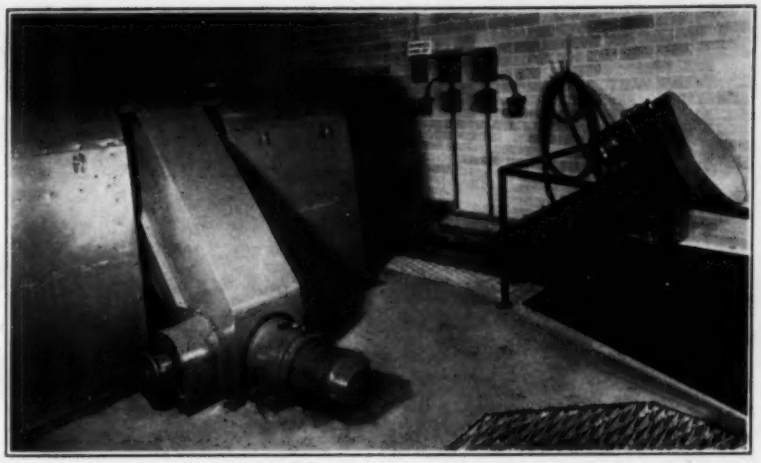
Balls of material have been known to accumulate on the grinder shredder plate which cause trouble later on in the plant as they finally drop off. It is believed advisable, when feasible, to return the discharge from grinders and triturators to the sewage ahead of the racks.

Other Operating Information

As typical examples of operating installations the following paragraphs set forth information on three plants.

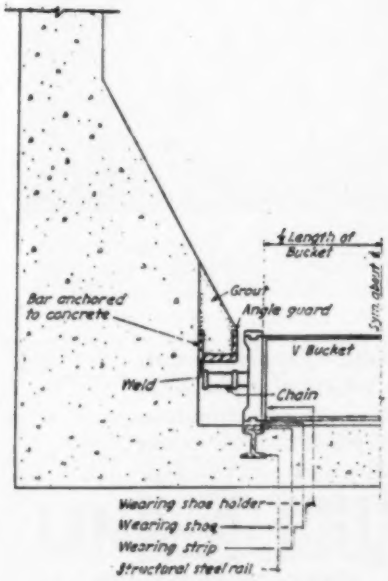
A mechanically cleaned bar rack and grinder as supplied by the Jeffrey Mfg. Co. was installed at the North Adams, Mass., sewage treatment plant during 1936 and has completed 13 years of operation. The maintenance work on the individual parts as reported by Paul Fleming, Plant Supt., has been very small. The rake jams occasionally if the chains become uneven, but this has not been considered serious by the operators. Automatic operation of the grinders is not employed as it has been learned from experience that large masses of rakings will clog the grinder necessitating opening it up and cleaning it out. New rotor weights have been placed on the hammers three times in 13 years. This involves only a moderate expense.

A mechanically cleaned bar rack and triturator as supplied by the Chain Belt Co. and installed at the Tonawanda, N.Y., sewage treatment plant was placed in operation in 1940. The operating experience has been reported to the author by James J. Kampas, Chief Operator, and Benjamin Hinkey, City Engr. The rake is operated either by time clock or manual control. Large objects have at times jammed the rakes at the bottom of the rack necessitating dewatering the rack channel for their removal. It has been found necessary to replace the rakes, bars, lower sprockets, and scraper arms because of wear and tear. The triturator teeth are periodically sharpened and need to be replaced on the average after two to three years of service.



Sheboygan, Wisc.—Two Rex Grit Collectors and Rex Separate Grit Washer

Inquiry has also been made as to the operation of the rack equipment at the Bloomington and Normal Sanitary District. In the January 1940 issue of Water Works and Sewerage the satisfactory operation of the Chain Belt mechanically cleaned bar rack and triturator was described by Orie J. Hendryx, then Supt. of the Bloomington and Normal Sanitary District. Mr. George L. Hall, the present superintendent of this plant, reports to the author that the original equipment is still in use except that the chain was replaced in 1948. Equipment to replace the lower boot section including sprockets and pins is at hand to make this replacement when it becomes necessary. Mr. Hall reports that the operation of the equipment during the past eight years has been satisfactory.



Typical section of corner of grit channel

2—Grit Chambers

The more prominent of the various means that have been used for the mechanical removal of grit from grit chambers at sewage treatment plants may be summarized as follows:

Scraper blades or flight conveyors
Bucket conveyors
Inclined flight conveyors
Inclined screw conveyors
Vertical bucket elevators
Belt conveyors
Grab buckets
Grit eductors and ejectors

The above equipment may be used separately or in various combinations. The grit may be collected at the influent end of channels by means of flight conveyors, scraper blades, or horizontal bucket conveyors, and then elevated by inclined flight conveyors, inclined screw conveyors, or by vertical bucket elevators or be pumped by eductors or ejectors. The grit as elevated from the individual channels may be then transported by means of flights, buckets and screw or belt conveyors to further treatment units or to points of disposal.

It is difficult to obtain manufacturers' agreement on recommendations for grit channel equipment. Each manufacturer has his own ideas as to what should be provided. These ideas are influenced, in part at least, by one of several reasons. Generally, the manufacturer desires to incorporate methods and equipment which: (1) he has tried and perfected to a reasonable working basis, (2) has become more or less standardized with the company, (3) he holds patents on, (4) will avoid infringement of patents held by others, or (5) will enable the manufacturer to compete on a favorable basis for the work of furnishing the equipment.

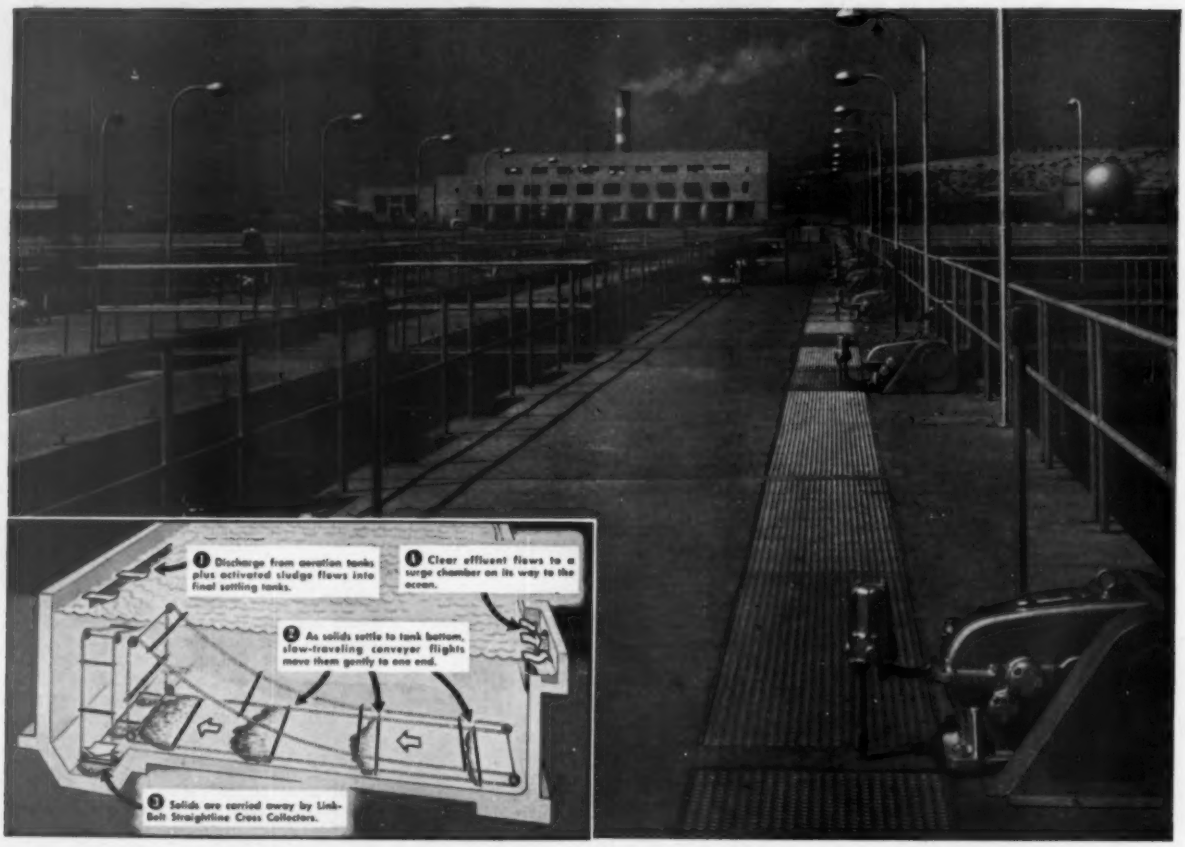
Severe Wear Encountered

The scraper blades and flights used for conveyors and elevators, the bucket conveyors and elevators or the inclined screen conveyors and elevators, all require moving equipment immersed or partially immersed in the sewage and grit. Due to the abrasive character of the materials handled and other operating conditions, grit chamber equipment of this type is subjected to a high rate of wear. In its design, therefore, the emphasis should be placed upon rugged, durable construction, with ready means for replacement of worn parts.

The operation of equipment in the grit chambers at Buffalo has been described by Johnson.[1] In these chambers the grit is collected by flights riding on rails embedded in the concrete floor. The shoes on the flights wore out rapidly and when replaced by shoes of highly resistant metal the soft steel guide rails wore down and had to be renewed. A design was developed in which the wear was taken by an easily replaceable wearing rail.

Tail bearing assemblies at the ends of the inclined screen conveyors were cut to pieces within a short time by the passage of fine grit particles into the bearing. The life of this bearing was prolonged by a combination of steel, rubber and paper gaskets with an adjustable packing gland which has excluded for a longer term and to a greater extent the working of abrasive material back into the bearing.

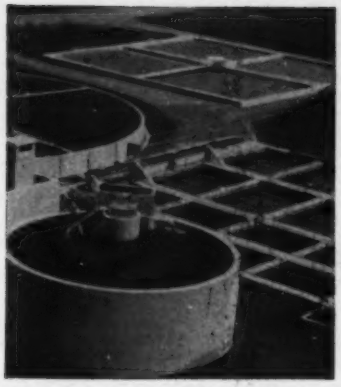
It pays to rely on LINK-BELT— ONE SOURCE...ONE RESPONSIBILITY for water, sewage and waste treatment equipment


1 Discharge from aeration tanks plus activated sludge flows into final settling tanks.
4 Clear effluent flows to a surge chamber on its way to the ocean.
2 As solids settle to tank bottom, slow-traveling conveyor flights move them gently to one end.
3 Solids are carried away by Link-Belt Straightline Cross Collectors.

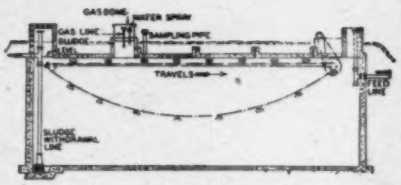
STRAIGHTLINE COLLECTORS — "Straightline Action," pivoted flights and peak-cap bearings mean top efficiency. Photo shows part of the 100 Straightlines in the final settling tanks at Los Angeles' Hyperion treatment plant. Storm peaks of 420,000,000 gpd can be treated at this $41,000,000 installation. Sludge is converted to fertilizer, gas to fuel.

IN MANY cities — large or small — Link-Belt sanitary engineering equipment provides efficient, long-life water purification and sewage treatment service. And in industrial plants of all descriptions, Link-Belt waste treatment equipment removes solids from waste water. Stream-pollution is abated and frequently valuable by-products are recovered.

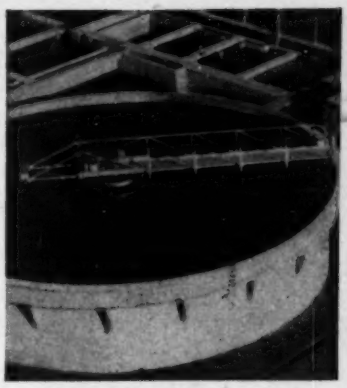
Shown here is part of the broad line of Link-Belt sanitary engineering equipment. If these photographs suggest a solution to your liquid waste handling problems, get in touch with the Link-Belt office nearest you. A Link-Belt sanitary engineer will be glad to work with your engineers, chemists and consultants . . . help you get the finest in modern treatment equipment. In addition, catalogs on these products are available on request.



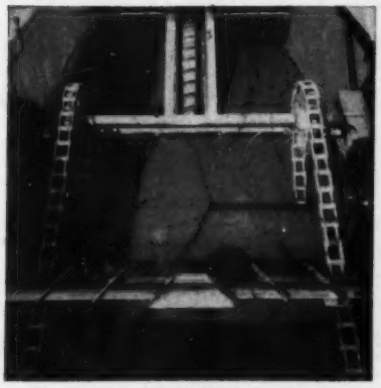
BIO-FILTRATION SYSTEMS use high-rate shallow filters and recirculation of effluent from filter to settling tanks in single- or two-stage treatment.



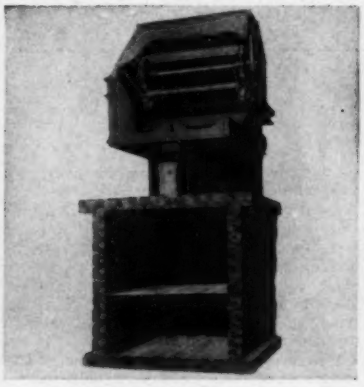
SCUM BREAKERS are installed in either round or rectangular digestion tanks to break up the floating scum as well as paddle down and submerge it. Mats of scum are prevented yet no breaking down by hand is required.



CIRCULINE COLLECTORS — "Straightline Action" assures quick, positive sludge and scum removal from the entire tank in the shortest time without septicity.

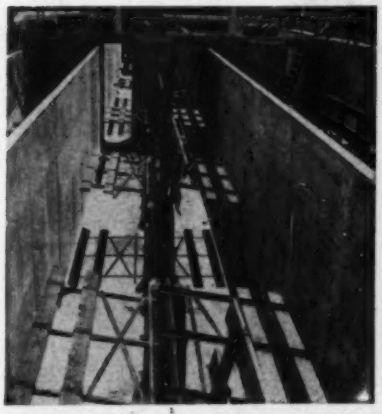


GRIT COLLECTORS AND WASHERS effectively collect, remove, wash settled grit and separate it from putrescible organic matter.



THRU-CLEAN BAR SCREENS — Remove large floating particles from large volumes of water, thus protect other equipment.

TRITOR SCREENS — For small sewage treatment plants — remove both grit and screenings with one mechanism.



CHEMICAL MIXERS — Link-Belt builds Straightline (shown) and flash mixers. Efficiency is assured by operation at variable speed for maximum floc formation.

LIQUID SCREENS have proved efficient and economical for removing solids from industrial liquids. Available in several sizes with coarse or fine cloth.

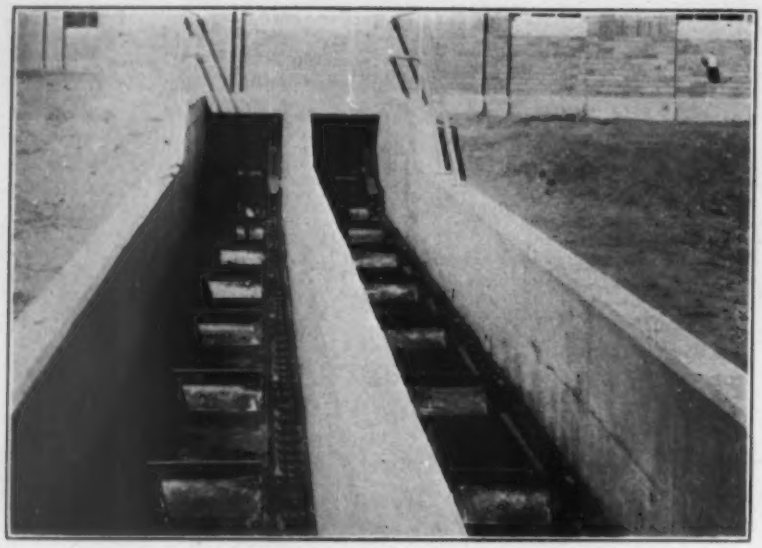
CONVEYORS AND ELEVATORS are built in a complete range of types and sizes for handling bulk or packaged chemicals. Leak-proof Flexmount Conveyor is shown.

OTHER LINK-BELT PRODUCTS INCLUDE: air diffuser units, non-clogging spray nozzles, traveling water intake screens, rotary screens, Roto-Louvre sludge dryers, chemical handling machinery, car spotters and haulage systems, a complete line of conveying, elevating and power transmission machinery.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13,400



Rock Island, Ill.—Jeffrey Grit Collectors

The grit chamber equipment at the District of Columbia Blue Plains plant was originally supplied with inclined screw conveyors with thrust bearings near the bottom of the grit hoppers. Because of continual submergence in grit, these bearings lasted only a very short time. To overcome this difficulty, the bearings were replaced by ball thrust bearings above the sewage level. In addition to eliminating the frequent failure of the underwater bearings, much smoother operation of these units resulted.

The grit chamber equipment at the Toronto Ashbridges Bay plant includes bucket conveyors and elevators on parallel endless strands of chain. The rails in the concrete channel bottom have readily replaceable wearing plates. The attachments supporting the buckets include removable wearing shoes of gray cast iron to ride on the rails imbedded in the channel bottom and on the angles supporting the return flight. The return angle rails and the removable wearing shoes are of ¼ in. thickness.

In an effort to reduce the wear on chains, attachments, shoes and rails, the Chain Belt Co. has devised and advocated construction as shown in the accompanying figure. This provides in effect a chain guard which prevents grit from falling directly onto or compacting directly upon the conveyor chain, thus reducing the abrasive action of the grit on the chain, its supporting attachments, and the guide rail.

Overload and Shear Pins

In the past, grit-collector equipment has been protected from overload largely by the use of shear pins. The objection to the use of shear pins has been that as these break under overload the operators have been inclined to replace them with stronger pins until a chain, sprocket, shaft or other element is seriously damaged or broken requiring major repairs. The development and use of stalling torque motors on grit chamber equipment so as to eliminate the use of shear pins was discouraged during the war and has been somewhat neglected since. Recently adjustable overload release devices have been advanced which are designed to mechanically disengage the grit collectors from the motor when overloads are encountered.

In order to secure truly competitive bids on grit chamber equipment, it may be necessary to provide detailed specifications and reasonably detailed plans.

The hunting tooth or extended life sprocket of alloy cast iron with a nickel content of 1.00 to 1.25 percent and a chromium content of 0.45 to 0.65 percent with teeth chilled to give a hardened wearing surface should give reasonable life.

Velocity Control

In many grit channels the effective removal of grit is dependent upon control of velocity. Various devices have been used to effect control so that a velocity in the vicinity of 1 ft. per second is maintained throughout the range of sewage flow from minimum to maximum for which the channel is designed. This may be accomplished by properly designed proportional weirs for rectangular channels which increase the depth of flow in direct ratio to the increase in rate of flow. This plan may require considerable loss of head at the grit channel during maximum rates of flow.

It is common practice at present to provide control sections following grit channels, such as the Parshall flume or the Camp regulator as manufactured by American Well Works,[3] and to design the cross-section of the grit channel to suit the backwater conditions created by the control section. Where the Parshall flume serves as the flow level control section for the grit channels, it is also usually adapted for measurement of sewage flow.[2] It is convenient to provide a flow indicator at the flume and adjacent to the grit channels so that the experienced operator can readily determine the number of channels which it is advisable to have in operation.

Grit Conveyors

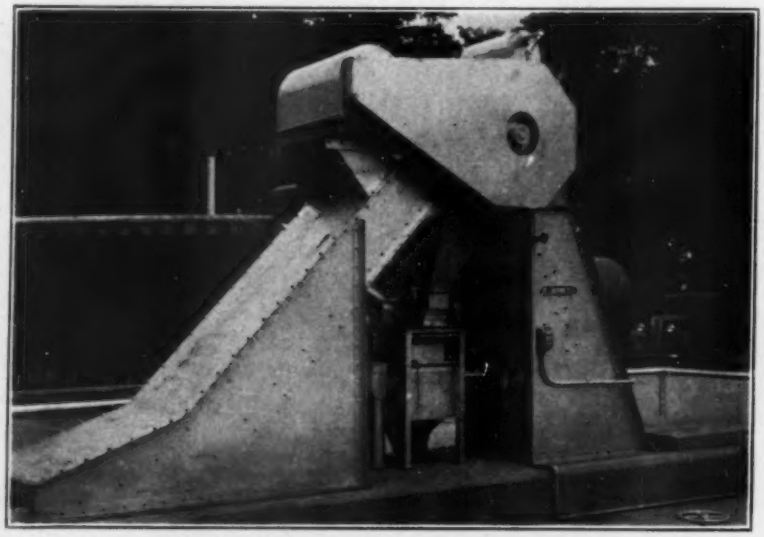
Belt conveyors for horizontal transportation of grit from multiple grit channels to grit-washing, storage, and disposal points, appear to operate with less maintenance costs than scraper, bucket, or spiral conveyors.

Pneumatic grit ejectors as made by Krajewoski-Pesant Manufacturing Co. are provided at the Tallmans Island plant in New York for discharging grit from the grit house to storage tanks in an adjacent building.

Fuller[4] reports successful operation with a pneumatic grit washer and ejector at Olean, New York. He states that formerly six man-days were required to remove the grit by hand, chain hoist, and truck, followed by burial, whereas the air-lift system washes the grit and disposes of it in thirty minutes. The washed grit is discharged to the Allegheny River. It is noteworthy that the air-lifted grit discharges through a 6-in. pipeline as compared with 3-in. and smaller pipelines used in connection with some grit eductors and jet pumps.

Grit Cleaning

The purpose of providing grit cleaning equipment is to remove the organic and putrescible materials settling with the grit so that the resultant product will be rela-



Wisconsin Rapids, Wisc.—Jeffrey Jigrit and Collector

tively free from objectionable characteristics, particularly odor.

A relatively clean grit can be obtained if the grit disposal conditions make this necessary. Under ordinary conditions of grit disposal in spoil areas, grit of satisfactory quality may be obtained by one of several different processes. In many plants, satisfactory results have been obtained by returning the grit as first removed, back to the inlet of the grit channels at the surface of the flow. The grit is thus washed in the sewage flow and after washing is again removed by the equipment provided therefor.

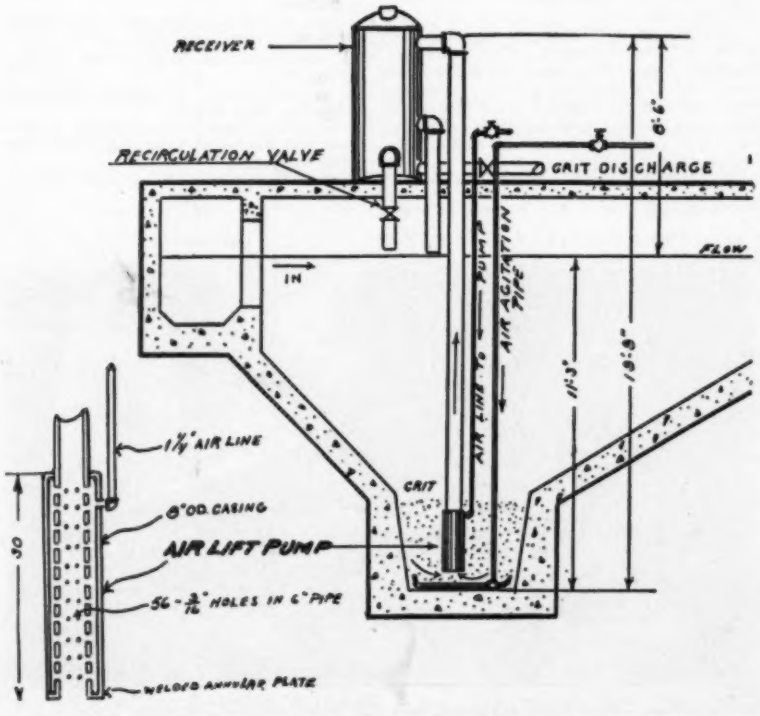
The Dorr detritor has been described and operating data from 41 installations has been reported by Kivell and Lund.[8] The detritor grit chamber is square in plan. The grit is collected at one side of the chamber by means of scraper blades on revolving arms, and is then elevated by means of reciprocating scraper blades working on an inclined plane. The reciprocating rakes create turbulence and a back and fill motion as the grit is carried up the slope, which tend to throw light organic materials into suspension.

Other manufacturers recommend the use of an inclined screw conveyor for removing the grit directly from the grit channels. The Link Belt equipment at Peoria and the Chain Belt equipment at the District of Columbia are of this type.

In some plants the grit as removed from the grit channels is deposited in separate grit-washing channels equipped with either inclined screw conveyors or reciprocating rakes.

The "Jigrit" washer as manufactured by Jeffrey has been installed at several New York City plants and has been selected for the Nut Island plant in Boston and the Ashbridges Bay plant in Toronto. The grit as removed from the grit channels is discharged to the "Jigrit" for separation by stratification and washing of adhering organic solids. The principal wearing part in the washer is the diaphragm which in some instances has required replacement on the average of once each year. The early tests of this equipment at the Indianapolis plant have been reported by Nichols and Tolman.[9]

Bristol, Conn.—Builders-Providence Parshall Flume Register and Recorder

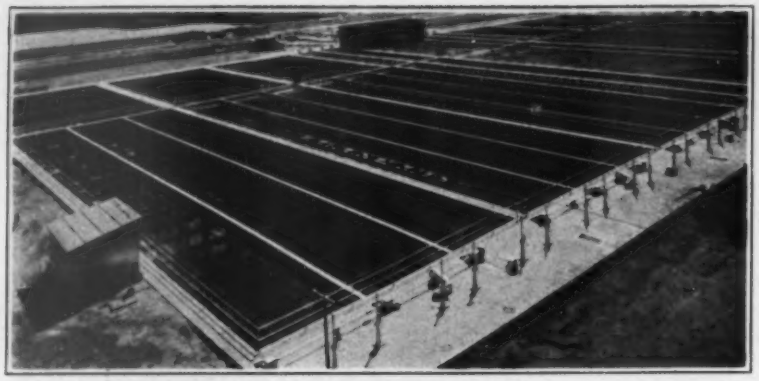


Olean, N.Y.—Details of pneumatic grit washer and ejector—After Fuller

Grit Storage

In mechanically-cleaned grit chambers of conventional design in which the grit is moved by means of flights, buckets or screw conveyors, the equipment must be operated as frequently as is required to prevent it from becoming buried in grit to the extent that it will not start up. Intermittent operation may be practical during dry weather, but frequently continuous operation is necessary during periods of storm flow. In many plants it is necessary to provide some form of grit storage facilities to act as a reservoir between the operations of grit removal and the filling of trucks to haul it away for disposal. Elevated storage bins have been quite commonly used. It has frequently been found that the grit compacts in the conical hopper bottoms of these bins above the grit draw-off gate, making it difficult to load the trucks. It has been found that air introduced to the grit bin just above the gate makes it possible for the grit to flow so that it can be drawn off readily and smoothly.

Particular attention should be given to the design and construction of gates beneath the storage bins. In several plants



Minneapolis-St. Paul—Chain Belt Rex Sludge Collectors and Automatic Skimmers

the gates installed have been difficult to operate manually and various expedients have been used, including extension of lever arms and, at one plant, by the addition of a block and tackle.

Provision should also be made for collecting and disposal of drainage from grit storage hoppers. A device consisting of a pan beneath the grit draw-off gate supported by a swiveled pipe arm which can be swung out of the way during truck-loading periods, has worked successfully.

Aerated Grit Channels

The accumulation of grit in aeration tanks, not preceded by sedimentation tanks or adequate grit chambers, has been observed for some time, particularly when the tanks have been equipped with elevated diffusers. Air has also been used in grit separation tanks in an attempt to separate out light organic materials. However, so far as we are informed, it is only recently that an attempt has been made to develop a rational basis of design for spiral flow aerated grit-separation tanks.

The apparent advantages of the aerated grit chamber as compared with other types are: (1) complicated control of velocity is not required, (2) variations of rate of flow through the chambers are of little importance, (3) the grit as removed does not require further washing for removal of organic materials, and (4) the grit can be allowed to accumulate in the grit hoppers and removed for disposal as may be convenient.

The most practical method of removal of grit from aerated grit channels will depend in part upon the size of the units. The Chicago Pump Co. has been interested in the development of the aerated grit chamber and its possible use in conjunction with pre-aeration tanks, possibly because of the use of swing diffusers in such tanks. This company has advocated the use of multiple hoppers under the diffuser system in which to collect the grit and its removal by means of jet pumps. The water used for pumping the sand would normally be plant effluent, pumped by a separate high-head pump. The grit-water mixture may be pumped to decanting tanks or grit drainage sand beds.

There is a lack of experience with this type of grit ejector so that it is not known whether it will work with satisfaction under any and all conditions. The foreseeable difficulty with the relatively small ejector nozzle and pipe is clogging with rags or other coarse materials removed with the grit.

The large scale aerated grit chamber installed at the Columbus, Ohio, sewage treatment plant has been described by Grant.[7] At this plant the grit is picked up from tank-bottom hoppers by a one-half-yard clam bucket suspended from a bridge crane with a 60-ft. span over the tanks. The bucket empties into dump trucks.

The aerated grit chambers at Columbus replace chambers of more conventional design. Except for the clam bucket there are no moving parts in the sewage so that wear and tear of equipment is reduced to a minimum.

It appears that aerated grit chambers may be used quite extensively in future designs. Their use in conjunction with pre-aeration tanks will be watched with interest. It appears desirable, for any sizable units, to provide fine mechanically-cleaned racks ahead of the aerated grit channels so as to reduce to a minimum the quantity of materials which could wrap around and collect on the diffuser tubes and air piping.

Incineration of Grit

The grit at the Buffalo sewage treatment plant was incinerated with the sewage sludge from September 1940 through April, 1941. It is reported that it was found possible to burn as high as 50 percent grit with 50 percent sludge for extended periods and occasionally for short periods to burn grit alone. However since April 1941 the grit which has about 40 percent volatile material has not been burned and has been transported to a disposal site without reported objection. According to Johnson[1] incinerating the grit caused excessive wear to equipment and caused plugging and clinkering in the ash removal system.

The grit removed at the Detroit sewage treatment plant has been incinerated in multiple hearth furnaces with the sludge cake.

The incineration of grit with screenings at Milwaukee in a multi-zone rabble furnace has been described by Lewers.[8]

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1 John W. Johnson, Works Supt., Buffalo Authority, Sewage Works Engrg., August, 1949, p. 386.

2 American Well Works, Bulletin No. 249.

3 Grit Chamber Velocities Controlled by Parshall Flume by Stanley T. Barker, WW&S, April, 1939.

4 Nelson M. Fuller, "Pneumatic Grit Washer" N.Y., WW&S, Oct. 1942, p. 449.

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6 R. D. Nichols and S. L. Tolman, Municipal Sanitation, Dec. 1938.

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8 George R. Lewers, WW&S, June, 1939.

Columbus, Ohio—Jeffrey Hunting Tooth Type Sprocket

Columbus, Ohio—Flight equipment with full depth attachments. Note insert type wearing shoes

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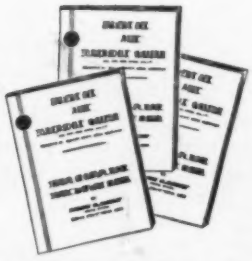

Reprints of the paper by Professor P. F. Morgan on the development of this Process, and a paper by Mr. James H. Blodgett on the Columbus installation are available on request.

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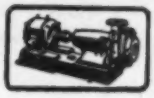


CHICAGO 14, ILLINOIS

Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

3—Settling Units

Sedimentation tanks have been designed in both rectangular and circular shape. Proponents of each design have their arguments and it is not the purpose of this article to comment on the merits of either.

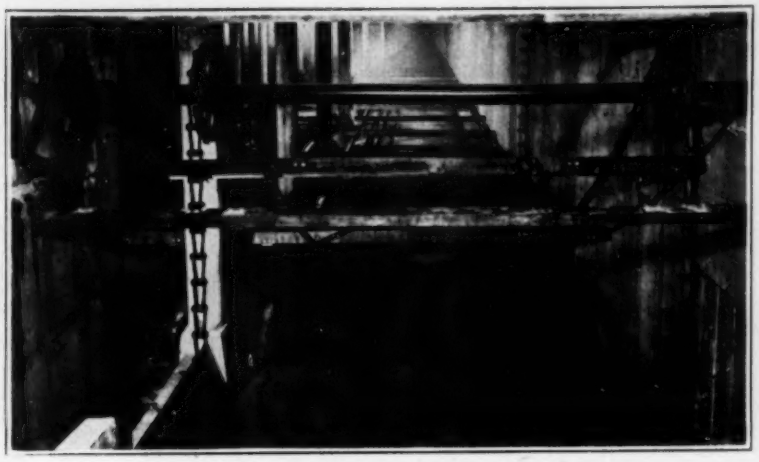
Rectangular Tanks

Equipment of this type is in a highly competitive field. For fair competition and in order to obtain the best equipment available with reasonable assurance of satisfactory operation and long life, it is desirable to specify the equipment in considerable detail. Manufacturers of this type of equipment include Chain Belt Co., Jeffrey Manufacturing Co., Link Belt Co., and Walker Process Equipment Co.

Chain and Flight Construction

Mechanisms include chains, flights, sprockets, shafts, and drive unit. The chains should be rugged and durable. Specifications commonly require that the chains be for the pintle type and made of processed malleable iron such as "Supermal," "Promal" or "Z-metal" with an ultimate tensile strength of not less than 70,000 psi. (pounds per square inch). The required working strength of the chain can be readily determined by consultation with the manufacturers and should be included in the specification so that all will quote on the same basis. Chains have been supplied with copper-bearing riveted steel pins. There is evidence that these pins wear and produce excessive elongation resulting in wear on the sprockets. Recently some of the manufacturers have recommended that the pins be of hardened steel.

Attachments for the chains to the flights at one time were commonly designed for bolting to part depth of the flight. There has accumulated some evidence of the flights splitting, under this condition, longitudinally beyond the attachments. Some manufacturers recommend a full depth flight attachment in order to strengthen the flights against this splitting. Because of the competitive situation, it is necessary to specify the full depth attachment if it is desired.



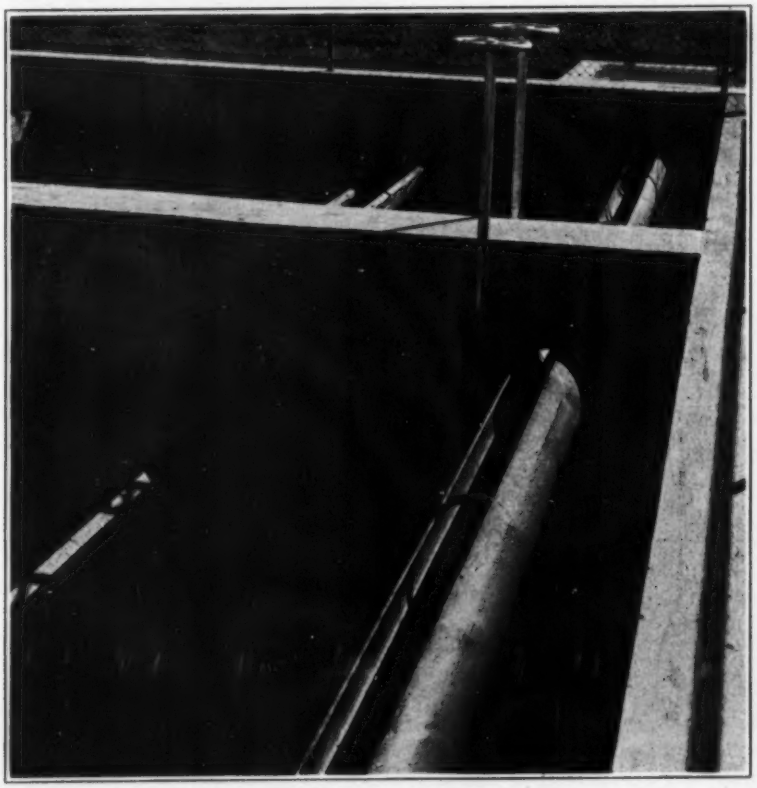
Toledo, Ohio—Link-Belt Straight Line Collectors

Flights are commonly specified to be of redwood. For the smaller tanks, sizes of 1⅝ by 5⅝ in. dressed, are suitable. For some of the larger tanks sizes of 2⅝ by 7⅝ in. dressed, appear advisable. The flights ride on rails embedded in the bottom of the tank for the collection of sludge and upon angles supported from the sides of the tank for the return flight. Wearing shoes are provided on the flights. Johnson[3] reported that replacement of these wearing shoes caused excessive labor and expense and recommended removable wearing shoes as illustrated in Fig. 1 of his paper. We have adopted this as standard construction and our specifications require that "The flights shall be provided with chilled cast-iron wearing shoes inserted into malleable-iron holders bolted to the flights at points of contact with rails in the tank bottom and with supporting angles." The castings must be of such workmanship that the removable shoe will not shake loose during ordinary operation of the flights.

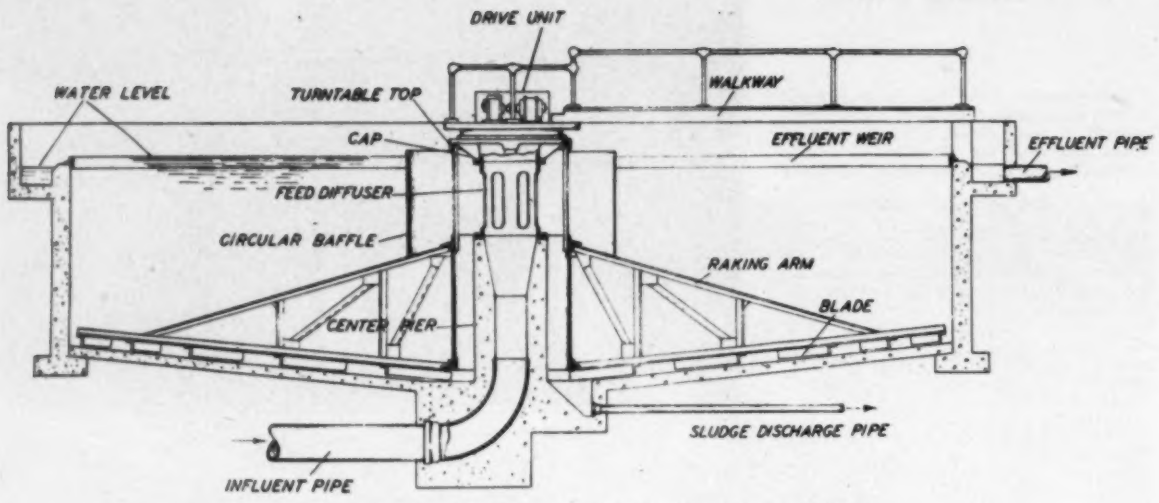
At the Minneapolis-St. Paul sewage treatment plant as reported to the writer by Kerwin L. Mick, Chief Engineer and Superintendent of the plant, the best answer to the shoe-wear problem, under the conditions at that plant, is the application by welding of two "Stellite" strips about ⅜ in. wide and about 2 to 2½ in. apart on each shoe. He reports that the wear on the bottom rails set in the concrete is not excessive and when it does occur, the situation is easily remedied by spot welding flat steel strips on top of the original rail. Some of such work was required in 1947 after seven years of operation with the "Stellite" strips.

Material improvements have been made in the sprockets. The "hunting tooth" or "extended life" sprockets are claimed to reduce wear on sprockets by about 50 per cent. Several of the manufacturers have agreed that it is desirable to specify sprockets of alloy cast iron with a nickel content of 1.00 to 1.25 per cent and a chromium content of 0.45 to 0.65 per cent. The sprockets should be chilled to give them a hardened tooth surface.

Recently a survey was made of chain-and-flight type sludge collectors in primary sedimentation tanks at 10 sewage treatment plants in New England with from 9 to 16 years' operating experience. There were 49 individual longitudinal collectors operating on the average for 11 years. The aggregate experience in repairs and replacements for all of this equipment is as follows:



Bristol, Conn.—Skimming pipes for scum removal



Cleveland, Ohio—Design of Dorr Center Drive Sifeed Circular Clarifiers

Drive chains, replaced in 2 tanks after 10 years of operation, a few links and pins replaced in 7 tanks.

Drive sprockets; 2 replaced.

Idler and take-up sprockets; 1 replaced, 1 redrilled.

Main chains; 1 broken link.

Flights; total of 20 replaced at 9 plants, replaced as broken at tenth plant with no record.

Flight shoes; no replacement at 7 plants, replaced after 11 years at 1 plant, replaced every 3 years at 1 plant and 12 individual replacements in 16 years at 1 plant.

Omitting one plant which operates the equipment continuously 24 hr. per day, the indicated life of the various parts, as reported by the operators, is 10 to 21 years for drive chains, 14 to 26 years for drive sprockets, idlers, and take-up sprockets, 13 to 24 years for main chains, 10 to 26 years for flights, and 3 to 19 years for flight shoes.

Mick of Minneapolis-St. Paul San. Dist., reports to the writer that all of the original main sludge collector chains in the Minneapolis-St. Paul sewage treatment plant sedimentation tanks placed in operation in 1938 are still in use. On two of the tanks, the chain would soon be worn through the barrel but it is planned to turn this chain over before that happens. The wear will then come on the other side of the barrel and it is expected that the life of the chain will be prolonged several years thereby.

Experience has disclosed that the life of the equipment may be prolonged and the cost of renewals and repairs reduced by operating the equipment in primary settling tanks for a few hours each day during sludge withdrawal operations. In small plants, chains and shoes which may require replacement at the end of 10 years for equipment operating 24 hours per day should last from 15 to 20 years if operated 1 to 3 hr. per day. For the largest plants more frequent replacement may be required.

Chain-and-flight construction is particularly adapted to covered sedimentation tanks as at Detroit, Boston Nut Island, Toronto Ashbridges' Bay, Los Angeles Hyperion primary settling tanks, among the larger plants; and Greenwich, Connecticut; Tonawanda, New York; Greenfield, Massachusetts; and Warren, Rhode Island, among the smaller plants. This type of construction is also advantageous for rectangular tanks in which it is desirable to remove the sludge rapidly and continuously so as to avoid deterioration in its quality.

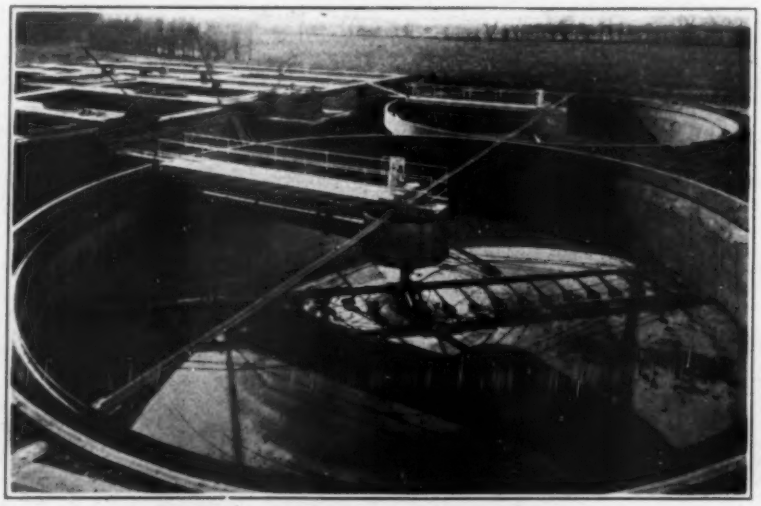
Overload Release

The most common method of providing against damage to the equipment because of overload is by shear pins. However, if a shear pin breaks because of overload the temptation is strong to put in a stronger pin and attempt to get the equipment moving rather than to unwater the tank and find out the cause of the overload. Major damage to equipment has been caused by the substitution or use of improper shear pins.

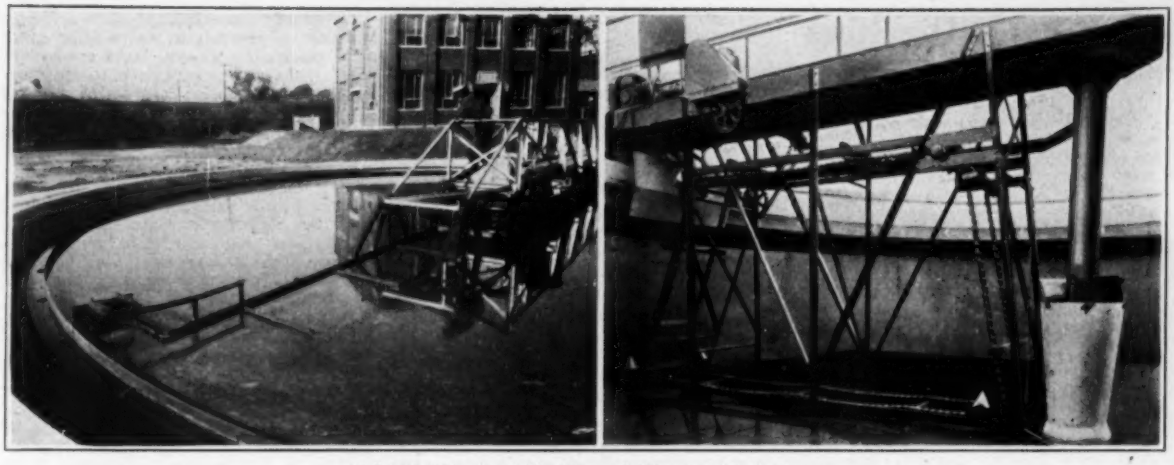
Several adjustable overload release devices have been developed to mechanically disengage the collector from the motor when overloads are encountered.

The Chicago Sanitary District is well satisfied with the operation of individual motorized reducers on sludge collectors. The basis of this design has also been described by Johnson.[1] All parts except the flights are designed to withstand the torque of the motor. Consideration must be given to the motor size and to selecting characteristics such that the maximum torque is not materially greater than the running torque. Particular attention should be given to possible deflection of shafts and consequent effect on bearing mountings. Self-aligning bearings are helpful to prevent difficulties of the latter type.

It appears advisable to specify that bolts shall not be less than ½ in. diameter and structural steel shapes shall have a thickness of not less than ⅜ in.



Topeka, Kan.—Chain Belt Tow-Bro Sludge Removers



Link-Belt "Circuline" Clarifier and Skimming Mechanism

Sludge Hoppers

Multiple hoppers for collection of sludge at the ends of rectangular tanks have caused operating headaches as the sludge tends to collect and hang up on the sides and in the corners. In time, this sludge becomes gas lifted and belches to the surface. The operator afflicted with this type of tank must spend considerable time pushing the sludge down to the bottom of the hoppers where it can be picked up by the pump suction. Even in relatively narrow tanks it appears advisable to provide cross collectors so that insofar as is practical, sludge is brought to the drawoff piping mechanically. In small tanks where longitudinal chain and flights have been used to collect the sludge at the ends of the tanks, it has in some instances proven practical to install cross collectors of the spiral conveyor type.

Scum Removal

Various types of mechanisms have been devised for withdrawal of scum from rectangular tanks equipped with chains and flights for sludge and scum collection. The rotated slotted pipe provides a simple means for manual control of scum withdrawal. (See acompanying cut for Bristol, Conn.) Where such manual control is too laborious it is possible to use mechanical means. One of the simplest mechanical skimmers consists of a rotating spiral squeegee which carries skimmings up a launder and discharges them into a scum trough, whence they are transmitted by water carriage to the disposal facilities. This type has been provided for the Los Angeles Hyperion primary settling tanks.

At the Boston Nut Island plant provision is made for conveying the scum while still floating on the sewage to one scum storage sump for each of two large rectangular tanks. The equipment is of the chain-and-flight type.

Crane-and-Bridge Type

Prior to 1939, the policy of the Dorr Co. was to recommend circular clarifiers wherever possible. As competition developed for their equipment in the circular tank field and as rectangular tanks with common walls were often preferred by some engineers under certain circumstances, the Dorr Co. developed and advocated the Monorake for sewage sludge removal from rectangular sedimentation tanks. This equipment was originally developed by them primarily to meet the need for mechanical removal of sludge from sedimentation tanks following "flocculators" in water treatment plants. The Monorake type of sludge removal equipment is reported to be available for rectangular sedimentation tanks up to 60 ft. wide and any reasonable length. This type of equipment includes a balanced raking mechanism supported and operated from a carriage spanning the width of the tank and traveling on longitudinal rails. The carriage is operated by cables. The rakes are so set as to collect the sludge in one or more hoppers at the influent end of the tanks. The first large installation of this type was at the Coney Island plant in New York about eight years ago. The principal difficulty encountered has been with failure of the reversing switch to operate. It is understood that the manufacturer has improved the design in this respect. The average life of the cables at this plant is said to be about five years. Other items of equipment requiring occasional replacement are cable sheaves, flight shoes, carriage wheels, and bearings.

One of main advantages of this type of mechanism is that the amount of equipment immersed in the sewage is reduced to a minimum and all equipment can be raised above the sewage level for renewals and repairs. Thus it is not necessary to unwater the tank for such work.

The Hardinge Co., Inc., makes sludge removal equipment for rectangular tanks consisting of a bridge crane which spans the width of the tank and supports the sludge scraper and skimmer. The sludge is collected in one or more hoppers at the influent end of the tank or in a trough equipped with a cross screw sludge conveyor.

Circular Tanks

The Dorr Co. has been the outstanding manufacturer of sludge removal mechanisms for circular sedimentation tanks. Also in this field are Hardinge Co., Yeomans Brothers Co., Infilco, Inc., and Chain Belt Co.

In the Dorr Type S clarifier, feed is introduced through a centrally located, inverted siphon with the inlet surrounded by a submerged diffuser. From the center inlet, the sewage flows radially to a peripheral weir. A motor-driven revolving rake sweeps the settled solids to a central discharge hopper in the tank bottom. Representative installations include the primary settling tank at the District of Columbia and the final settling tanks at the Cleveland Easterly plant. L. M. Johnson[1] has described the advantages gained by the use of stalling torque motors to drive equipment of this type at the plants in the Chicago Sanitary District. The clarifiers in the 126-ft. diameter final settling tanks at the Chicago Southwest plant are driven by ½-hp. motors through 69,500 to 1 combination helical and spur-gear speed reducers. The motor constitutes the only protective device throughout the entire gear train.

Tanks of this type afford only a small hopper for sludge accumulation. For the Dorr clarifier at the Terminal Island plant in Los Angeles, the operators report that it is desirable to provide automatic programmed intermittent operation of the raw sludge pumps in order to withdraw reasonably well concentrated sludge.

In very large circular final settling tanks, wind currents and high rates of weir discharge for a single peripheral weir have been reported to induce the discharge of unduly large quantities of suspended solids with the tank effluent. The unit weir discharge rates may be substantially reduced by the provision of supplementary weir capacity in connection with an effluent trough built within the tank and supported from the outside wall.

There is evidence to show that, on the average, the cost of maintenance, renewals, and repairs on sludge removal equipment in circular tanks is relatively low.

The sludge withdrawal pipelines from circular tanks are of necessity longer than for rectangular tanks. There is very little evidence to show that this has caused unusual operating difficulties except at the Buffalo plant. Here the sludge withdrawal lines became plugged with grit and heavy sludge to a serious extent as reported by John W. Johnson.[2]

Various devices have been developed for collection of scum on the surface of circular primary sedimentation tanks. The collection is sometimes effected by wind currents. Several instances have been observed where the operators have improved upon the standard form of scum collector supplied by the manufacturer but the improvements have not been described in the technical literature.

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1 L. M. Johnson, Mun. Sanit., Nov. 1938, p. 529.
2 J. W. Johnson, Sew. Wks. Engr., Aug. 1944, p. 386.

4—Sludge Digesters

Considerable mechanical equipment is usually involved in modern separate sludge digestion systems. Among the more important items requiring consideration are, floating covers, gasometer-type covers, fixed steel covers, heating systems, sludge removal, recirculation systems, gas collection, supernatant withdrawal and scum control.

Floating Covers

John R. Downs, Superintendent of the Joint Meeting Sewage Treatment Plant at Plainfield, N.J., is credited with the design of the first floating cover for a separate sludge digestion tank in the United States. The simple wooden cover designed by him has been developed by the Pacific Flush Tank Co. into a modern mechanism built of steel with guides, controls, supernatant selectors, pressure and vacuum relief valves, gas domes, manholes, sampling hatches, level indicators and other appurtenances. The original floating cover patents have expired and other companies now compete for the floating cover business. This relatively new competitive condition places a responsibility on the engineer to draw up plans and specifications which will assure truly competitive bidding and that his client will receive equipment which will meet the requirements for service and long life.

The engineer is also responsible for weighing the costs and comparative advantages and disadvantages of the floating covers with gasometer and fixed covers of various types and forms.

There has been some experience with tilting of covers with resultant jamming and some damage to the equipment. Guides and extended rollers have been used in some instances for the purpose of controlling tilting.

Under certain conditions floating covers have been known to freeze in a fixed position for several weeks at a time. Heat has been applied to the annular ring between the cover and the tank walls to correct this condition.

The natural weight of the floating cover may not provide the desired gas pressure. In some instances weight has been added to the cover to increase the gas pressure.

The floating covers ride on the liquid surface or scum. Provision should be made to prevent the rapid loss of heat through the cover. This can normally be accomplished by covering the roof over the ceiling plate with corkboard, foam glass or other insulating material. The insulating material should be protected by roofing. In some instances heat has been applied to the air space between the ceiling plate and roof in order to heat the top of the digestion tank[1].

Gasometer Type Covers

The gasometer type of cover has been extensively used by the Dorr Co. in the secondary tank of its so-called Mult-digest system. It is also quite commonly used where engineers desire a relatively small volume of gas storage and find it convenient to provide this at a digestion tank, or a sludge storage tank, rather than in a separate holder. The depth of gas storage under the gasometer cover is usually on the order of 2 to 6 ft. or more. The Dorr Co. has used a center column and Pacific Flush Tank Co. has used a spiral guide, to prevent tilting of the gasometer cover.

Fixed Steel Cover

The Dorr Co. has commonly used a fixed-steel cover on the roofs of primary digestion tanks in its Mult-digest system. Competitive bids between fixed steel domes and fixed concrete roofs for the large digestion tanks at the Los Angeles Hyperion Plant in 1948, favored concrete dome roofs.

Heating Systems

For about 20 years prior to 1947, the majority of digestion tanks were heated by means of hot water circulated in coils within the tanks. These installations if designed with ample area and operated at relatively low temperature of hot water, if constructed of suitable materials and joints, if adequately supported and if not seriously affected by electrolytic action, have given very satisfactory service. There are enough "ifs" in the design, construction, and operation of those heating coils so that failures have been recorded.

Recently the tendency has been away from the use of hot water coils inside the tanks towards enclosed heat exchangers outside the tanks. This has been promoted in part by the sales efforts of the manufacturers, particularly at first by the Pacific Flush Tank Co. and more recently by Walker Process Equipment Co., the Dorr Co., and others. The separate heat exchangers are usually designed to heat the raw sludge being admitted to the tank or liquor circulated from the tank. In the latter case, the heated recirculated liquor may be added to the raw sludge for rapid conditioning.

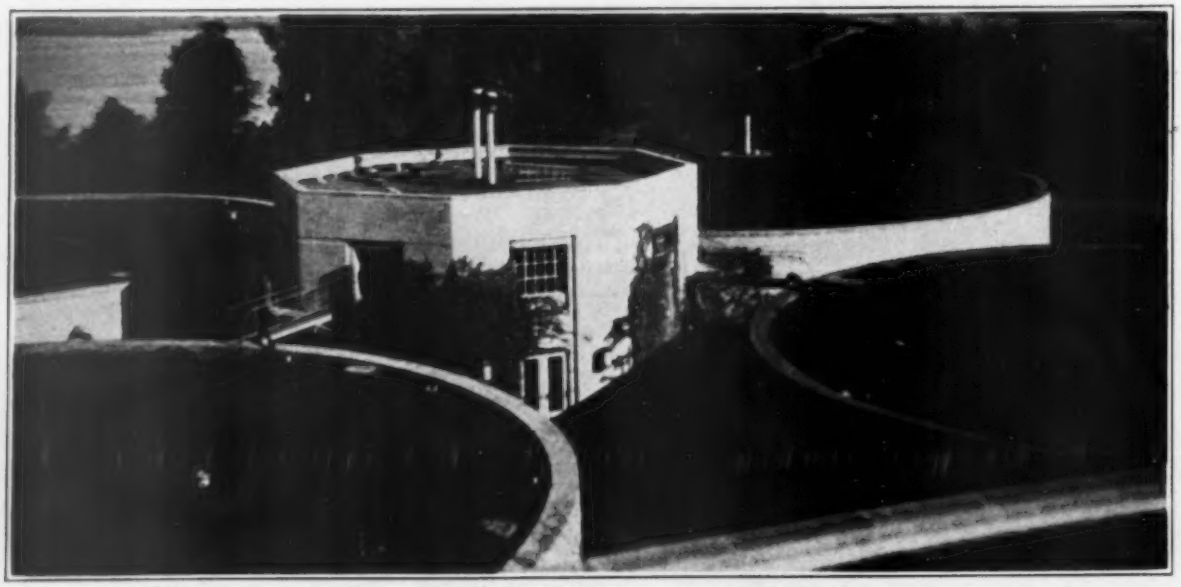
Direct contact combustion heaters have been installed in the digestion tanks at Baltimore[2] and at Philadelphia[3] and the control of temperature in digestion tanks with live steam has been described by Rawn[4].

The digestion tanks at the Los Angeles Hyperion plant are heated by means of steam admitted into the flow tube below the impellers of Dorr mixers. The steam is reclaimed from the vapor phase system at the dual fuel gas diesel engines. Where direct steam heating is used, the water should be treated as required to prevent operating difficulties at the steam boilers.

Infilco, Inc. has developed a so-called "Verti-Flo" impeller for installation in the scum zone of digestion tanks. Heating coils are installed at the mixer in a vertical bank which can be withdrawn through a manhole in the roof.

Scum Control

Possibly the greatest single difficulty experienced with the operation of sludge digestion tanks has been in accumulation of masses of relatively inert scum which renders ineffective a substantial proportion of the tank capacity, clog supernatant and overflow pipes, and create numerous operating problems. It appears that if the scum



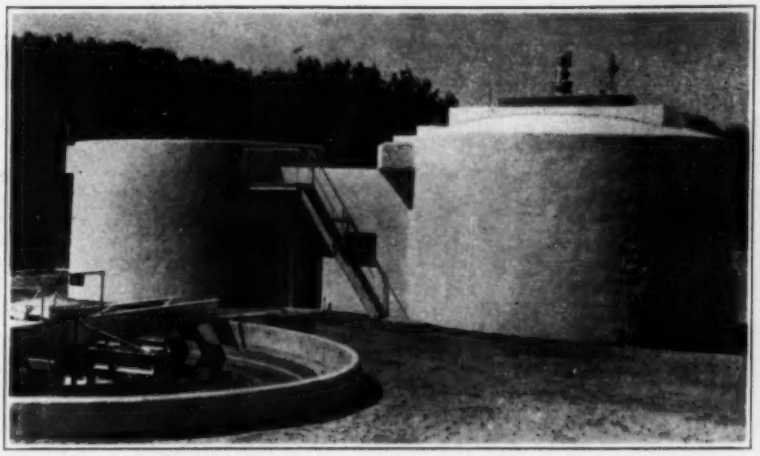
Separate sludge digesters with P.F.T. Floating Covers—Buffalo, N.Y.
Sludge control house, center, has P.F.T. heat exchangers, control devices, and pumps

is kept well mixed with warm tank liquors, the scum-forming materials will continue to digest and for the most part settle to the bottom with the sludge. If well lubricated by tank liquors, excess accumulations of floating materials can be withdrawn through piping connections in the upper portion of the tank.

Several schemes have been developed designed to meet the scum problem. A few will be briefly described. In tanks equipped with floating covers, the Pacific Flush Tank Co. recommends the installation of a circulation system designed to produce a flow and mixing action at the center of the tank in the gas dome. In theory, scum accumulating under the floating cover and outside the limits of the gas dome will flow into the center and receive treatment.

The Dorr Co. recommends the installation of propeller mixers installed in the scum zone below the roofs of fixed-roof tanks. These are designed to mix the scum with the underlying tank liquor. Favorable results have been reported with this equipment at Stamford, Conn. Units of this type have been installed in the digestion tanks at the Hyperion Plant in Los Angeles. Where particular types of industrial wastes conducive to the formation of very heavy scum masses are to be encountered, this company has recommended mechanical mixers with slowly revolving stirring arms passing between fixed teeth suspended from the roof. Similar equipment is supplied by Hardinge Co., Yeomans Bros. Co., and Infilco, Inc.

For circular fixed roof tanks, the author[9] has recommended the circulation of liquor at relatively high rates, the liquor being drawn from beneath the scum zone and discharged just above the normal liquid or scum level. Four discharge nozzles are provided located at about quarter points in plan and inclined at about 45°, directed so as to cause a circulatory motion in the scum and to bring scum not directly under the nozzles into the active turbulent mixing areas. An installation of this type on a primary digestion tank, 50 ft. in diameter, at Bristol, Conn., has proven very effective in quickly eliminating a mass of heavy scum which formed during the early weeks of operation before the circulating liquor was discharged through the scum nozzles above the liquor level. After this heavy scum was eliminated, it has been found practical to restrict scum accumulation to a relatively thin soft layer by operating the recirculation system a few hours each day.



Dorr Co. Multidigestion System at Carmel, Calif.

For square or rectangular tanks, the Link-Belt Co. makes a scum breaker which consists of a number of paddles attached to a pair of endless chains moving through the scum at a speed of about 1 fpm. The return flight is through the mid depth of the tank.

Sludge Removal Mechanisms

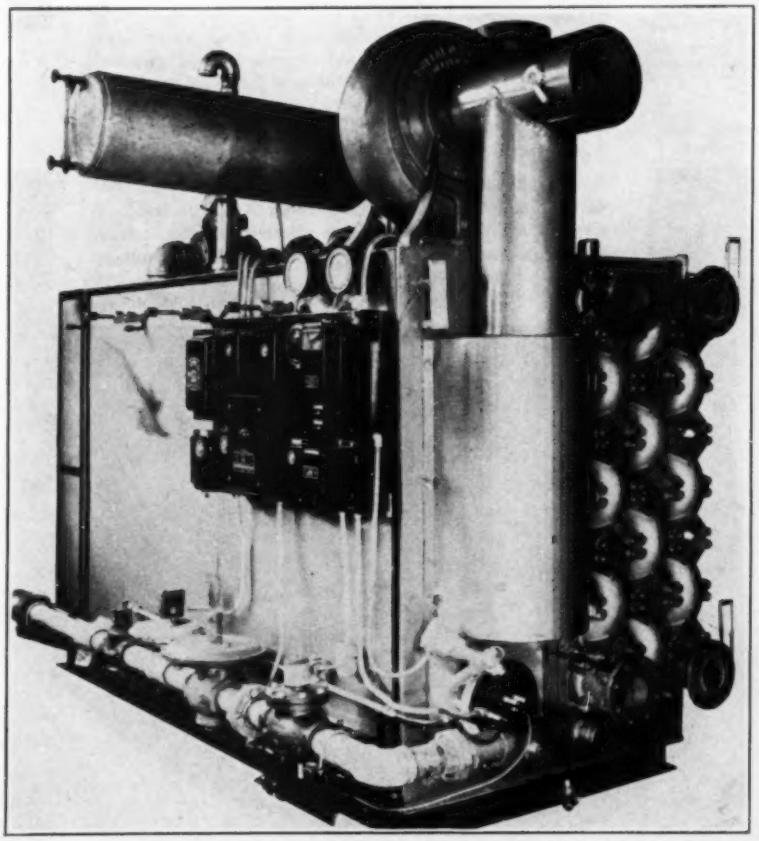
In the earlier designs, digestion tanks were equipped with sludge removal mechanisms similar to those provided for circular and rectangular sedimentation tanks. The operation and maintenance of this equipment proved to be difficult and expensive. Recently circular tanks have been provided with inverted conical bottoms to promote the withdrawal of sludge without the aid of mechanical equipment. Relatively few rectangular digestion tanks have been built or proposed during the recent years.

Supernatant Withdrawal

Normally as raw sludge digests there is a separation of relatively dilute liquor from the concentrated sludge or scum. This dilute liquor usually collects over the bottom sludge and under the scum layer. In the majority of plants multiple pipe connections are made to the tanks in the zone where dilute liquor is most apt to collect and provision is made for supernatant withdrawal by selection after sampling, to determine where the clearest liquor may be obtained.

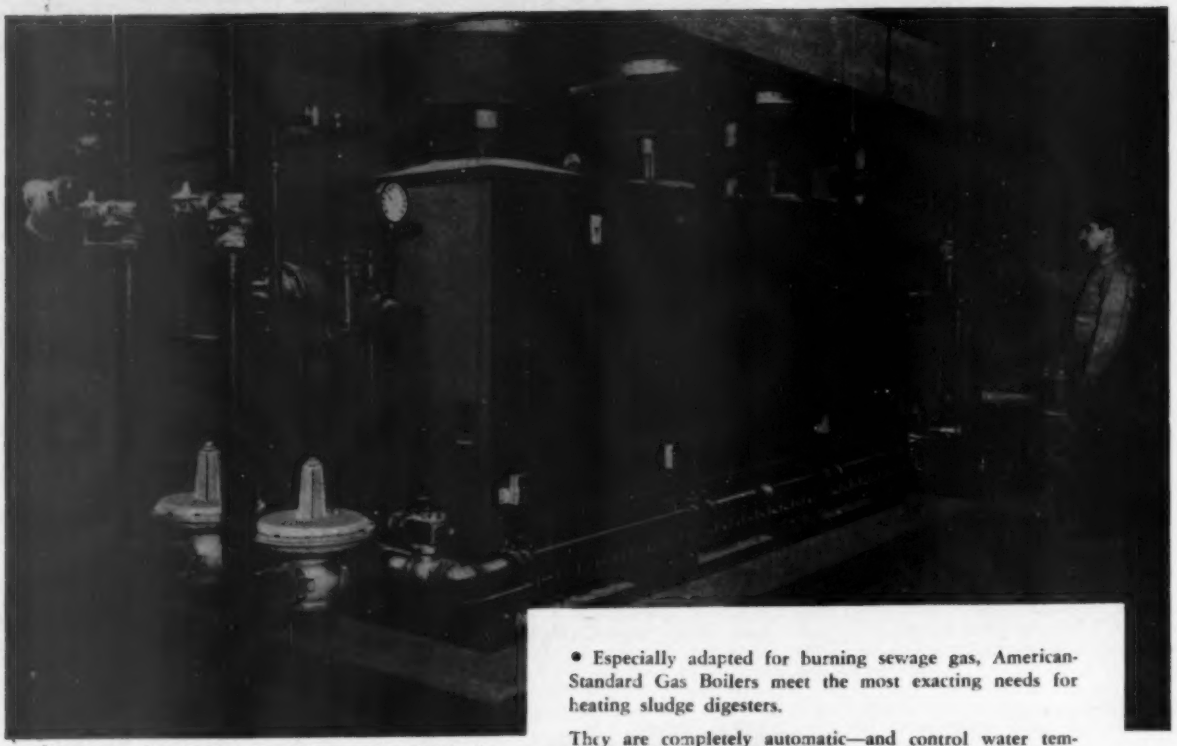
The new tanks at the Hyperion plant in Los Angeles are equipped with a swivelled supernatant withdrawal pipe operated by means of a cable and winch rigging. The cable passes through the tank roof by means of a Varec fitting designed for a 12-in. water seal.

The Pacific Flush Tank Co. advocates the use of its "Supernatant Selector." This consists of a slotted tubular device mounted vertically at the central portion of the digester and extending throughout the portion of the depth from which supernatant is normally withdrawn. The tube is made with slots that are intended to be sufficiently narrow to hold back liquid containing large amounts of suspended solids and to pass the clearer liquid for withdrawal from the tank. Provision is recommended for backflushing as needed to clear the slots.



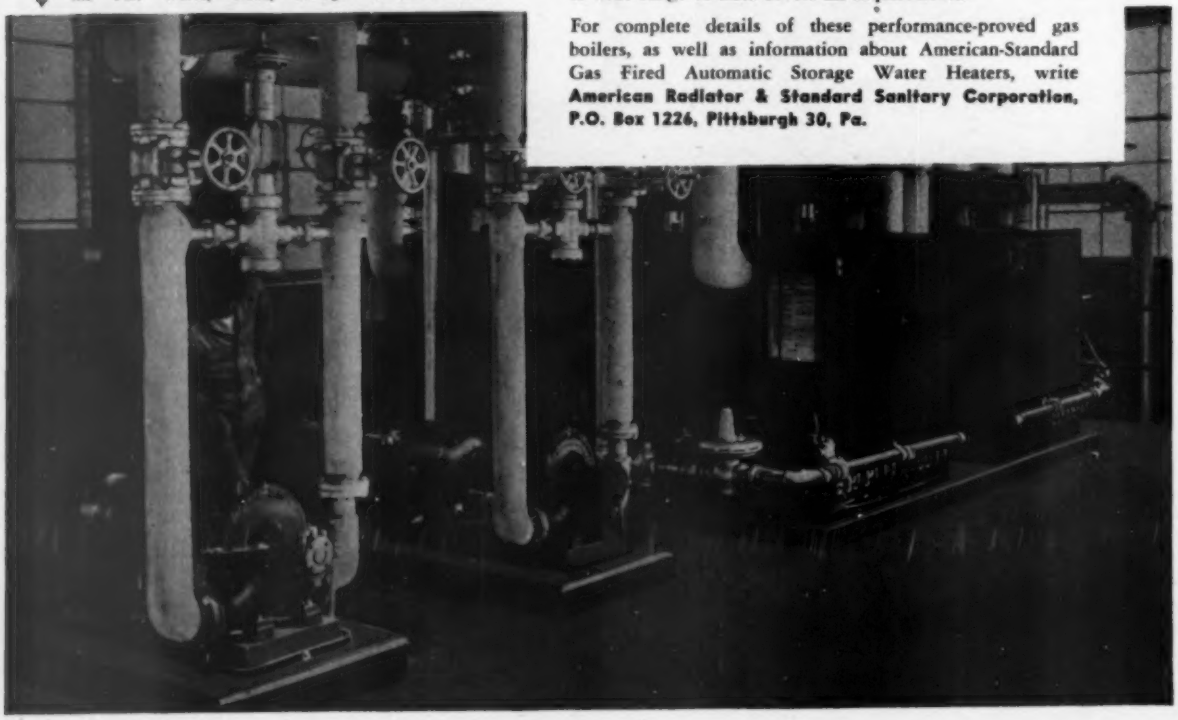
P.F.T. Hot Water Type Heater and Heat Exchanger—Stockton, Calif.

AMERICAN-Standard GAS BOILERS . . .



↑ Two American-Standard Gas Boilers are installed in the Northeast Sewage Treatment Plant, Philadelphia, Pa.

↓ Five American-Standard Gas Boilers are installed in the Fort Worth, Texas, Sewage Treatment Plant.



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BOILER NO.		OUTPUT PER HOUR			INPUT PER HOUR		BOILER SPACE		
Steam	Water	BTU per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	BTU per Hour	Cu. Ft. 700 BTU Sludge Gas	Over-all Hgt. xx	Floor Space Width	Floor Space Depth
	1-GA-4E	31,500		210	39,375	56	40½"	16	19¼"
	1-GA-5E	42,000		280	52,500	75	40½	16	22¼
	1-GA-6E	52,500		350	65,600	94	40½	16	25¼
	2-GA-4E	63,000		420	78,750	113	54⅜	16	19¼
	2-GA-5E	84,000		560	105,000	150	54⅜	16	22¼
	2-GA-6E	105,000		700	131,250	188	55½	16	25¼
	2-GA-7E	126,000		840	157,500	225	55½	16	28¼
	4-GA-8E	147,000		980	183,750	263	54	16	37¼
	4-GA-9E	168,000		1,120	210,000	300	54½	16	40¼
	4 GA-11E	210,000		1,400	262,500	375	54⅝	16	46¼
0-GS-4E		61,200	255		76,500	109	53⅛	16	33¾
0-GS-5E		81,600	340		102,000	146	53⅝	16	37¾
0-GS-6E		102,000	425		127,500	182	54⅛	16	41¾
1-GS-4	1-GW-4	144,000	600	960	180,000	258	57⅜	19	25
1-GS-5	1 GW-5	192,000	800	1,280	240,000	343	59¾	23	25
1-GS-6	1-GW-6	240,000	1,000	1,600	300,000	429	60¼	27	25
1-GS-7	1-GW-7	288,000	1,200	1,920	360,000	517	62⅜	31	25
1-GS-8	1-GW-8	336,000	1,400	2,240	420,000	600	63¼	35	25
1-GS-9	1-GW-9	384,000	1,600	2,560	480,000	686	65	39	25
1-GS-10	1-GW-10	432,000	1,800	2,880	540,000	771	65⅝	43	25
4-GS-6	4-GW-6	480,000	2,000	3,200	600,000	857	74⅞	27	41½
4-GS-7	4-GW-7	576,000	2,400	3,840	720,000	1029	76⅝	31	41½
4-GS-8	4-GW-8	672,000	2,800	4,480	840,000	1200	78⅛	35	41½
4-GS-9	4-GW-9	768,000	3,200	5,120	960,000	1372	79⅞	39	41½
4-GS-10	4-GW-10	864,000	3,600	5,760	1,080,000	1573	81½	43	41½
4-GS-11	4-GW-11	960,000	4,000	6,400	1,200,000	1715	83	47	41½
4-GS-13	4-GW-13	1,152,000	4,800	7,680	1,440,000	2060	76⅝	41½	
4-GS-15	4-GW-15	1,344,000	5,600	8,960	1,680,000	2400	78⅛	41½	
4-GS-17	4-GW-17	1,536,000	6,400	10,240	1,920,000	2740	79⅞	41½	
4-GS-19	4-GW-19	1,728,000	7,200	11,520	2,160,000	3086	81½	41½	
4-GS-21	4-GW-21	1,920,000	8,000	12,800	2,400,000	3425	83	41½	
4-GS-22	4-GW-22	2,016,000	8,400	13,440	2,520,000	3600	78⅛	41½	
4-GS-25	4-GW-25	2,304,000	9,600	15,360	2,880,000	4120	79⅞	41½	
4-GS-28	4-GW-28	2,592,000	10,800	17,280	3,240,000	4625	81½	41½	
4-GS-31	4-GW-31	2,880,000	12,000	19,200	3,600,000	5145	83	41½	
4-GS-33	4-GW-33	3,072,000	12,800	20,480	3,840,000	5480	79⅞	41½	
4-GS-37	4-GW-37	3,456,000	14,400	23,040	4,320,000	6165	81½	41½	
4-GS-41	4-GW-41	3,840,000	16,000	25,600	4,800,000	6850	83	41½	

xx To top of Draft Hood

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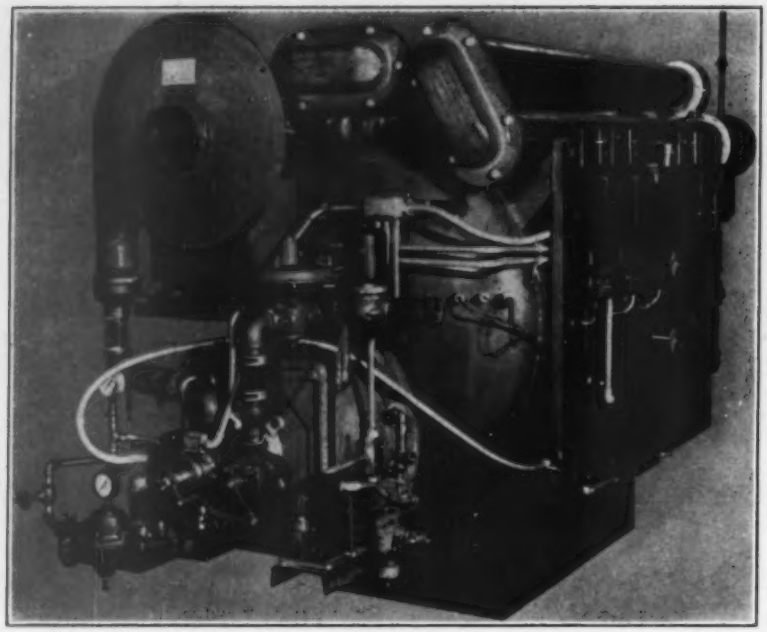

East Lansing, Mich.—Walker Process Equip. Co. Heat Exchanger

Gas Domes

In some early designs of digestion tanks, gas was withdrawn from a low, small dome, not much more than a manhole cover, in the roof not far above the sludge level. Experience soon indicated the need for larger and taller domes as under high rates of gas production there was at times sufficient disturbance of the liquid surface under the dome to carry moisture and particles of sludge and scum into the gas system. With domed roofs, the clearance between the liquid level and dome at the center of the tank is usually sufficient to minimize the requirements for a separate gas dome. For flat concrete roofs and floating covers, more elaborate gas domes should be provided.

Pressure and Vacuum Relief

Sludge digestion tanks, regardless of the type of roof, require provision for pressure and vacuum relief. Undue pressure within a tank may be created by sludge inlet pumps operating at a time when all outlets to the tank are closed or clogged. A vacuum may be created by the withdrawal of sludge at a greater rate than sludge is being admitted or sludge is being introduced.

Early designs of pressure and vacuum relief devices which relied on a "leg" of oil or water proved somewhat troublesome because of evaporation, freezing, "blowouts" or other difficulties.

Vapor Recovery Corp., Pacific Flush Tank Co. and others have developed valves which permit gas to escape from the tank if the pressure rises above a predetermined level or permits air to enter the tank if there is a tendency for vacuum to form. These valves are equipped with flame arresters to prevent a flame from flashing back into the tank when the vacuum release feature is operating.

Careful attention must be given to the design and operation of these valves. In one type of valve, some trouble has been experienced due to freezing of condensation in such a manner as to render the valve inoperative during severely cold weather. In another type of valve, the protection afforded depends upon the replacement of oil which may evaporate or be accidentally displaced.

Normally the floating cover is not subject to vacuum. However, in the event sludge is withdrawn while the cover is resting on the landing ledge, a sufficient vacuum can be created, unless a vacuum relief valve is provided, to cause serious structural damage to the cover.

General Comment

Particular attention should be given to the protection of structural steel members, cables, and other metal parts immersed in sludge digestion tanks from the corrosive effects of sewage sludge and possibly also from galvanic or electrolytic action. The difficulties encountered in the latter respect in a sludge digestion tank at the Terminal Island plant in Los Angeles have been described by Parkes[6].

Oil and grease lubricated bearings should not be used inside of digestion tanks. It is preferable to support rotating equipment from the structural roof using thrust bearings.

Piping should be designed of generous size. Maximum rates of gas production may be several times the average rate and should be provided for. Undersized sludge inlet and withdrawal piping has led to serious difficulties in a number of instances.

For the most part, the equipment installed within digestion tanks prior to World War II has not proven very satisfactory. The work of cleaning out a digestion tank and the making of repairs on mechanical equipment installed therein is laborious and distasteful to the operators. In many small plants with only one or two tanks, the withdrawal of one tank from operation to make repairs may necessitate by-passing a portion, if not all of the sewage flow, during the repair period.

It is hoped that the newer developments will prove longer lasting and more effective than some of the earlier.

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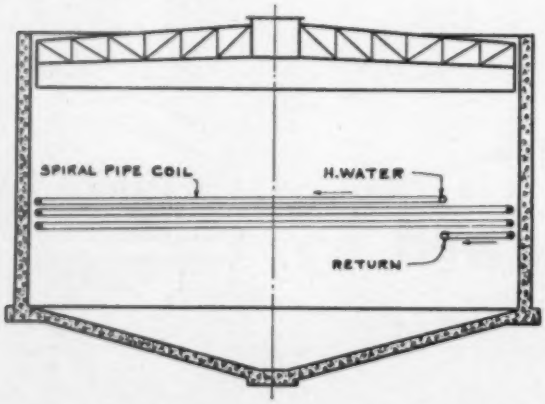
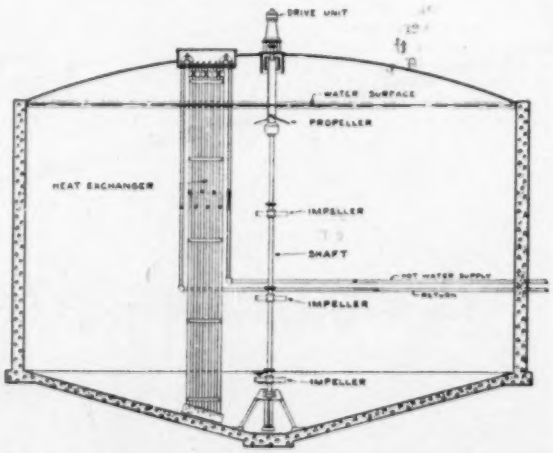
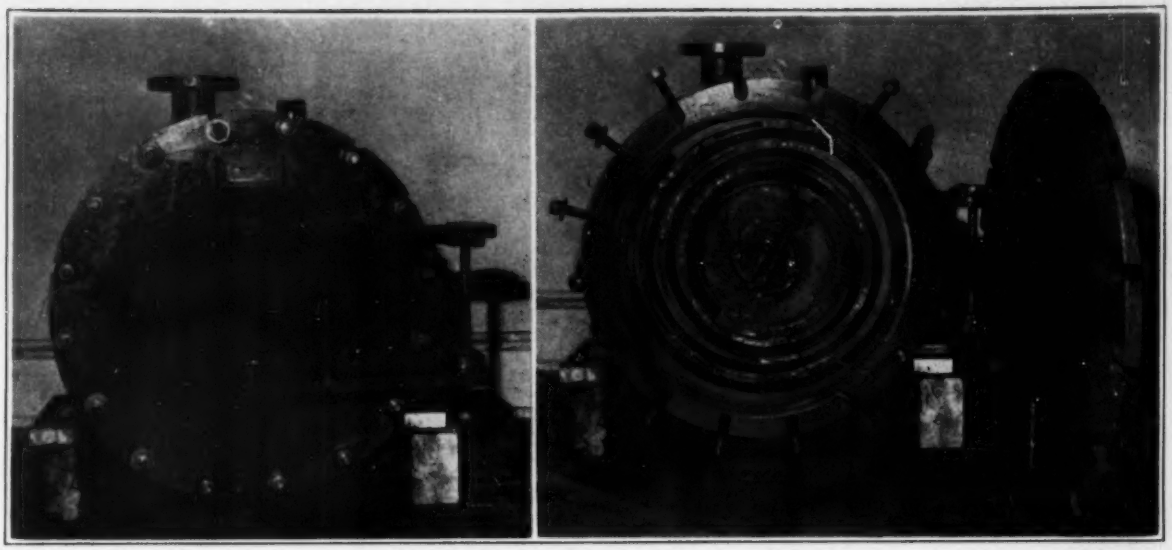


Digestion tank with spiral pipe internal heating coil (after Wittwer)



Digestion tank with vertical bank heat exchanger (after Wittwer)



(With front door closed) Dorr Co. Counter Current Flow Type Spiral Heat Exchanger (With front door open)

5—Vacuum Filtration of Sludge

Mechanical dewatering by vacuum filtration of raw primary sludge has been employed at the Minneapolis-St. Paul sewage treatment plant since 1938. At this plant the sludge was conditioned prior to June, 1947 principally with ferric chloride and lime. As a five year average the dosages of ferric chloride was about 1.1 per cent and of lime about 3.1 per cent, both on the dry basis.

Following June, 1947, ferric sulfate was used in the place of ferric chloride when it was found impractical to obtain the latter chemical. During the early years of operation it became evident that the screens and woodwork were built up with excessive amounts of calcium carbonate which prevented the free passage of water into the interior piping system. It was learned that the periodic use of a hydrochloric acid bath containing an inhibitor resulted in the prevention of any major buildup of carbonate and at the same time extended the average life of filter cloth by 150 hr. to 200 hr.

In order to provide for washing of the filter cloth while the filter keeps on producing filter cake, the washwater pipe and spray nozzles were moved from their original location on the far side of the filter from the take-off plate, to a new location immediately behind and below the top edge of the take-off plate. The washing is done on the section of the drum between the take-off plate and the line of submergence in the filter pan. The spent washwater is collected in a trough which drains back to the settling tanks. Since November, 1947, the filters are washed at least once each hour for at least one revolution of the drum. Well water is used at a pressure of 50 to 70 psi.

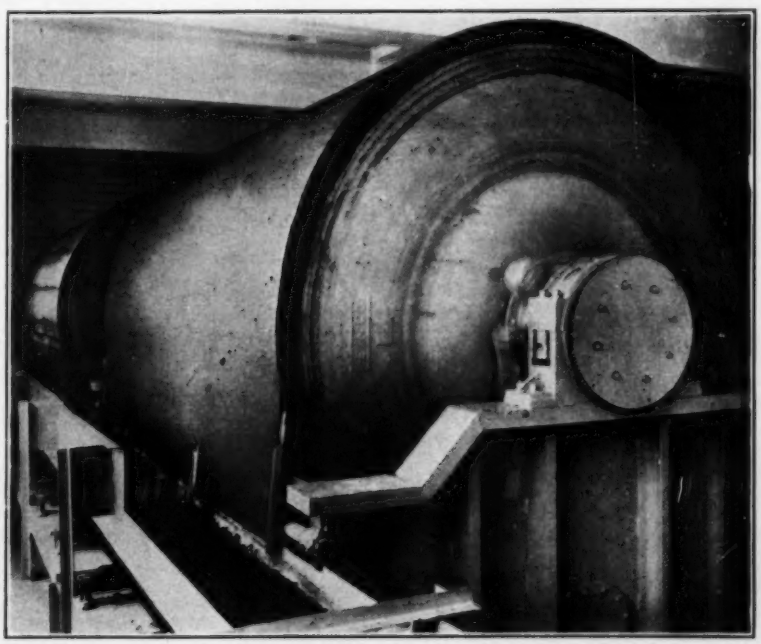
The operators state that the new method of washing has reduced filtration costs, increased the filter area available and produced a more even feed to the incinerators.

The ferric chloride or ferric sulfate and lime process used for conditioning raw sludge at Minneapolis-St. Paul is also used for conditioning other raw and digested sludges. Wherever lime is used, conditions such as encountered at the Minneapolis-St. Paul plant may be anticipated and the materials of construction should be designed to take care of normal operation with alkaline sludge and for occasional washing with inhibited hydrochloric acid.

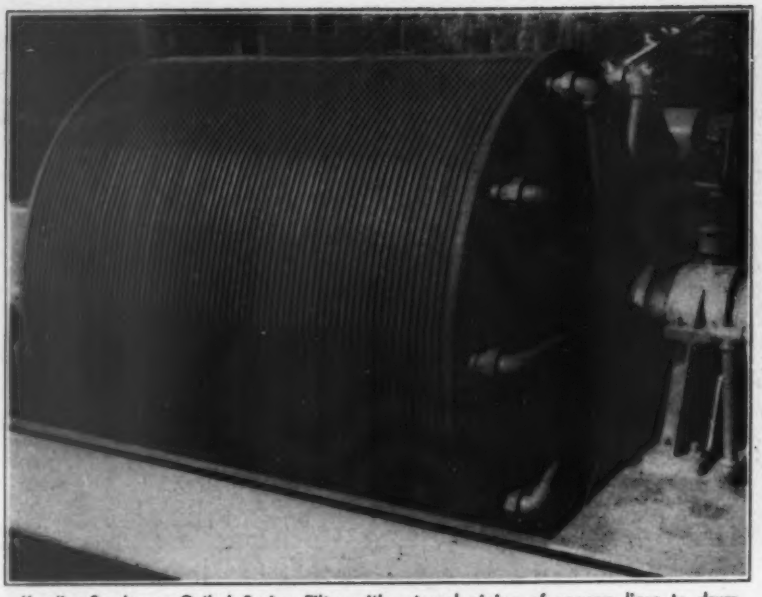
Acid Conditions

When sludge is conditioned with ferric chloride alone, as may be the case with waste activated sludge and with digested elutriated sludge, the materials of construction should be such as to resist corrosion from ferric chloride solution under acid conditions. In smaller plants or otherwise where the filters operate only a few hours each day, corrosion of filters constructed without due regard to the ferric chloride condition sometimes does not show up for several years. Where the filters operate practically continuously, however, corrosion of the filters of conventional construction may become troublesome in a matter of months.

For acid conditions it appears advisable to specify acid-resisting bronze screens, staples, division strips, etc. The pipe and fittings between the drum compartments and the trunnion conduits should be highly resistant to acid conditions. Heavy-walled chemical hose, with the individual lines supported to prevent the formation of moisture traps and to prevent movement when the drum is revolved, has been advanced as one solution to the problem. "Saran" tubing, manufactured by the Dow Chemical Co., has been used but there has been some



Norfolk, Va.—Eimco Filter



Komline-Sanderson Coiled Spring Filter with external piping of vacuum lines to drum

question of the permanency of the joints particularly inasmuch as there has been some plastic flow in pipelines made of "Saran." However, J. K. Adams[1] has reported that "Saran" piping in the vacuum filters at the Tenafly, New Jersey, sewage treatment plant has developed no leaks since the installation was made in 1944, the filtrate containing ferric chloride and having a pH of 4.0 to 5.0.

For the filters at the main Toronto plant, pipe and fittings of "Uscolite" as made by U.S. Rubber Company have been accepted for filtrate piping where sludge is to be conditioned with ferric chloride.

A newer model of vacuum filter has all vacuum piping connections outside the filter drum, thus greatly facilitating their repair or renewal.

Recent developments in the cord and coiled-spring-wound filters are promising. These filters do not require any filter cloth as the filter cake forms over the cord or spring coils and drops off as the filter media changes direction over an idler shaft off to one side of the filter drum.

Sludge Agitators

Agitators are sometimes supported from the trunnion shaft of the filter. It has been asserted that this method of support produces frictional resistance to the rotation of the drum when the agitator swings in a reverse direction, results eventually in a jerky operation in large drums and causes undue wear on the vari-drive mechanism. For this reason, some engineers recommend that the agitators be supported on bearings below the trunnion shaft, or on the ends of the filter tank. The frequency of agitator oscillations depends upon the size of the tank and the characteristics of the sludge. The driving mechanism should be of variable speed to accommodate possible requirements.

Cake Take-off Plate

The sludge cake take-off plate should be provided with a replaceable cutting edge. For acid conditioned sludge this cutting edge has been specified to be of 18 per cent chromium and 8 per cent nickel-steel alloy, at least 3/16 in. thick.

1 Sewage Works Journal, April, 1950, p. 562.

Cake Slicers and Distributors

Unless some provision is made for cutting it up, the cake from the filter may drop off in large masses which create somewhat of a problem on the belt conveyors customarily provided for carrying the cake to a point of disposal. A reasonable design is to provide replaceable steel pins about ⅜ in. diameter threaded on one end for screwing into tapped holes on the cake apron. The pins should be spaced 8 to 12 inches on centers horizontally.

It is frequently helpful to provide a device for distributing the cake on the conveyor belt. This may be accomplished by mounting rotating cutting blades over the conveyor operated by a connection from a shaft on the conveyor. Experience at Hartford, Conn., and elsewhere has demonstrated that these cutters should revolve in the direction of travel of the belt. If they operate against the travel of the belt, there is a tendency for the cake to pile up in back of the cutters. The cutting blades are subject to considerable wear and should accordingly be designed to resist abrasion and for convenient replacement.

Auxiliary Equipment

Sludge Feed

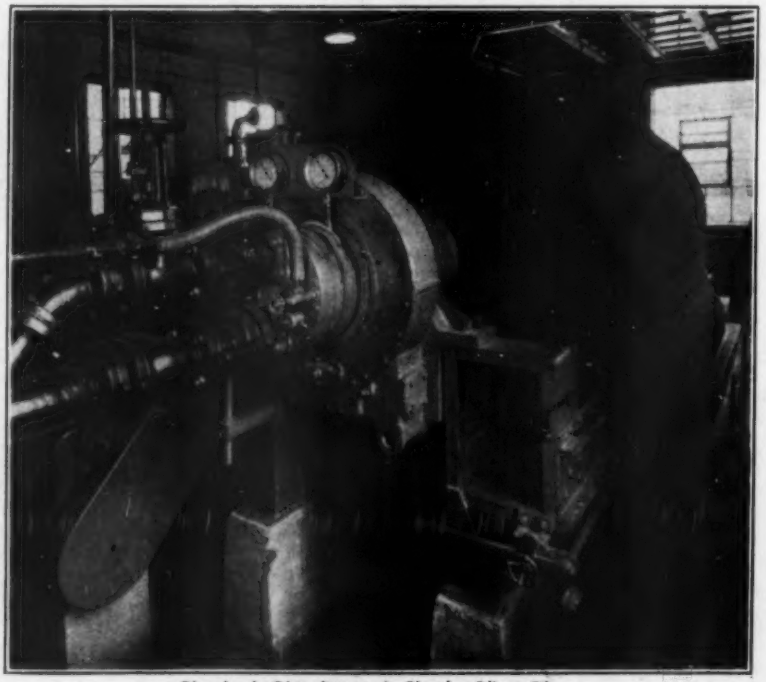
In the larger installations, sludge is commonly fed to the conditioning tank ahead of the filter by bucket elevator operating from a sludge well. The elevator may advantageously be driven through variable-speed transmissions under electrical control, designed so that the sludge will be elevated at the rate of filtration and the sludge load in the conditioning tank and filter tank will be maintained within approved limits. Floats of hard rubber or glass with tape or chain of acid-resisting materials have been used in float chambers at the sludge conditioning tanks, with electrical transmitting devices designed to operate in connection with the electrical controls at the variable-speed transmissions on the bucket drives.

Ferric Chloride System

The handling, storage, making up of solution and the application of ferric chloride to sludge for conditioning ahead of vacuum filters, create multiple problems because of the extremely corrosive nature of the material.

Ferric chloride in liquid form is commonly stored in rubber-lined tanks. Where large storage capacity is required as at the Hyperion Plant in Los Angeles, the liquid ferric chloride may be stored in reinforced concrete tanks with a protective covering such as "Amer-coat."

Ferric chloride pumps have not always proven satisfactory. Other solution feed equipment is available, if desired, or it is



Cleveland, Ohio (Westerly Plant)—Oliver Filter

COILFILTER

The only completely modern Sludge Vacuum Filter

NON-CLOGGING

PERMANENT FILTER MEDIA

CONSTANT OUTPUT

LOW OPERATING COST

COILFILTER

...ATEST IMPRO...

IN SLU...

...g filter
...scharge of
...—and, with-

...TER MEDIA

...mployed as filter media
...th or mesh. Cannot rot,
... be periodically removed
...shing or replacement.

OUTPUT

...r media, completely cleaned
...ring cycle, maintains uniform
...ut the entire filter run, making
... controls unnecessary.

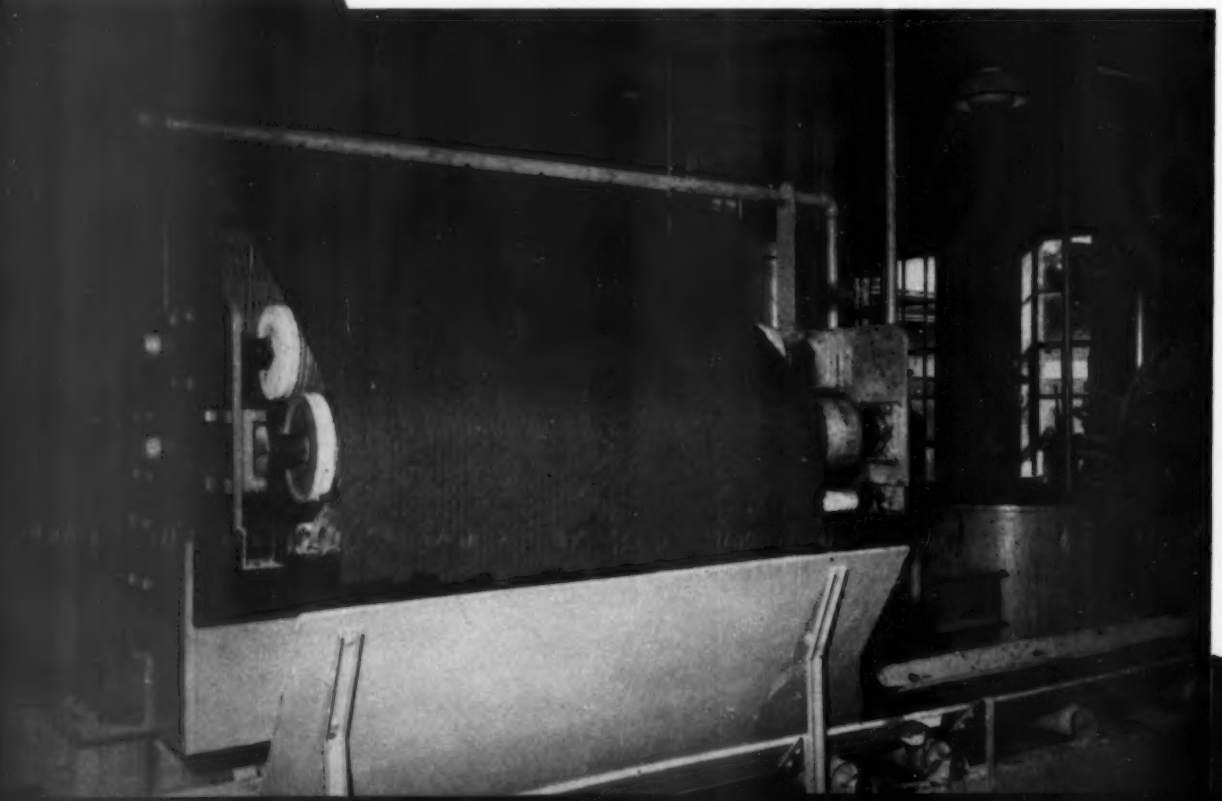
...RATING COST

...remove or replace. All piping
...ach. Non-corrosive, non-rotting
...n. For sludges requiring chem-
... chemicals are needed. Simple

The Komline-Sanderson Coilfilter is the modern vacuum filter, designed for modern sludge dewatering requirements. Output is constant and maintained at peak level because the Coilfilter employs no filter cloth to become progressively more clogged with each turn of the drum. Coilfilter dewatering is accomplished by two layers of alloy steel coiled springs 0.410" in diameter placed in corduroy fashion (see full scale line drawing on opposite page) around the drum.

Upon completion of the dewatering cycle the two layers of springs leave the drum and are separated from each other by discharge rolls in such a manner that the filter cake is lifted off the lower layer of springs and discharged from the upper layer with the aid of a positioned tine bar. The two layers are then washed separately by spray nozzles and reapplied to the drum by grooved aligning rolls. Coilfilter design allows the springs to flex in opposite directions while being washed, thus assuring that the filter media entering the vat is always completely clean—that there can be no blinding or clogging—that output remains constant.

No sludge dewatering system employing filter cloths can match Coilfilter effectiveness without complete removal and washing of the filter media after each turn of the drum, a situation obviously not economically feasible.



MENT

E DEWATERING IN THIRTY YEARS . . .

PERMANENT FILTER MEDIA

Filtering media of the Komline-Sanderson Coilfilter are made up of a series of helically coiled springs fabricated of alloy steel or other metal suitable to the particular application. Each spring is separate and made endless by joining the two ends with a threaded plug. Such media has a useful life of many years, with obvious operational advantages.

RUGGED CONSTRUCTION— EASY MAINTENANCE

Basic, simple design and rugged construction make the Coilfilter outstanding from the standpoint of both operation and maintenance. In addition to the permanent type filter media, the drum surface is constructed of alloy steel. There are no wooden staves, built-up drainage grids, backing screen, or wire winding. Coilfilter piping is simplicity itself. All piping is straight and external to the drum. Should it ever require cleaning or replacement, this can be accomplished quickly and easily from the outside of the drum, rather than the inside, as with other vacuum filters.

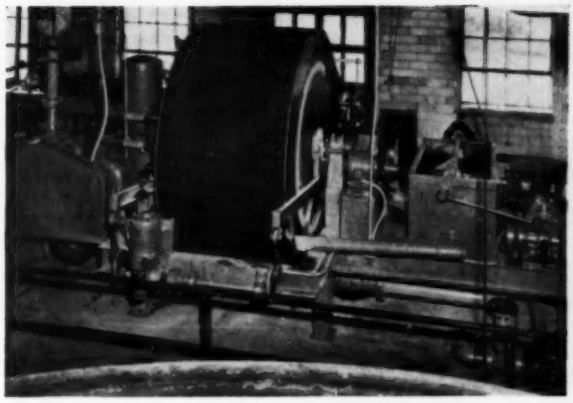
FRESH SOLIDS DEWATERING

The Coilfilter dewaters fresh sewage solids directly, at higher filter rates and lower conditioning chemical requirements. The Consulting Engineer is thus offered the opportunity to economize on his basic plant design, and at the same time simplify plant operation. This feature is of particular importance to smaller municipalities, but in all cases results in appreciable savings in both initial and operating costs. The proper application of hydrated lime and ferric salt to fresh sludge deodorizes not only the sludge, but the filter cake as well.

REPLACES SLUDGE DRYING BEDS

Several recent Coilfilter installations which replaced sludge drying beds at post-World War II plants have emphasized the fact that sand beds often do not meet actual plant requirements. When enlargement is indicated, land may not be available. This results in overloading of digesters, which in turn affects operation of the entire plant.

Coilfilter dewatering is the answer. Less plant area is required, less labor is required, and most important, dewatering can be put on a regular schedule, independent of weather conditions.



A Coilfilter installation is usually less expensive than sludge drying beds where the population equivalent is over 10,000. It may also be indicated for smaller plants under special conditions, particularly when plant area or appearance are critical.

COILFILTER PERFORMANCE

Output of filter cake is greater than from any other type of sludge dewatering equipment, making possible smaller plants at lower cost.

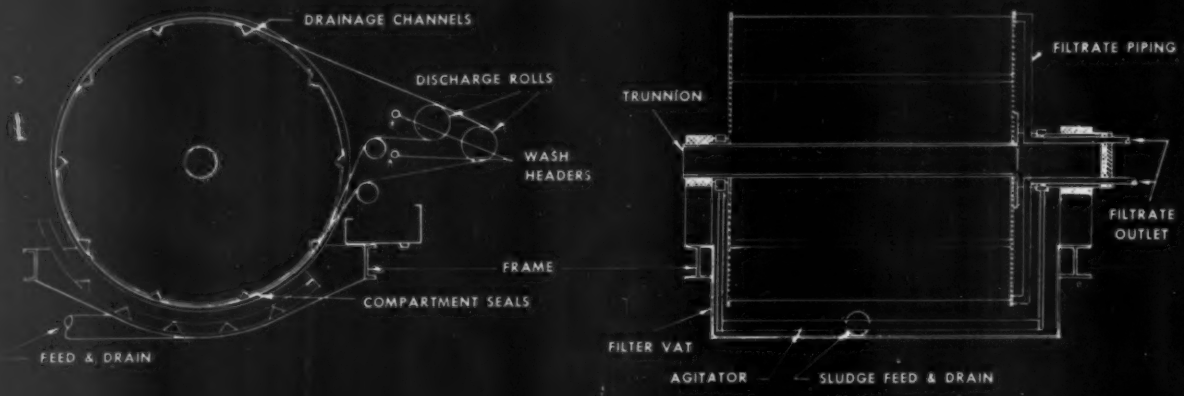
Chemical conditioning is far less critical than with other types of vacuum filters.

Sudden changes in sludge characteristics do not upset Coilfilter operation.

Filter cake is uniform in moisture content because filter media cannot clog or blind.

Standby filters are not necessary, since the equipment does not have to be taken out of operation for cover changing or replacement.

The Coilfilter . . . for improved sludge filtration



PROVED AND TESTED

The Komline-Sanderson Coilfilter is field tested and proved. A demonstration unit moved about the country from one filtration assignment to another has repeatedly out-performed the equipment regularly used for the same function. Experience data compiled from these extensive tests and the many Coilfilter installations enable Komline-Sanderson engineers to estimate the adaptability of Coilfilters to a wide variety of sludges. In order to assume complete responsibility for the proper performance of the Coilfilter installation, it is a company policy to furnish all necessary equipment, including the following:

1. **Coilfilter**
2. **Vacuum and Filtrate Equipment**
3. **Conditioning Tank**
4. **Wet Sludge Handling Equipment**
5. **Conditioning Chemical Feeders, Pumps and Tanks**
6. **Cake Handling Equipment**

Our engineers will be glad to submit preliminary performance estimates involving the use of Coilfilters in your plant, upon receipt of the following information:

1. **Type of treatment plant**
2. **Whether sludge is to be digested**
3. **Design data, including flow and suspended solids or population equivalent**
4. **Number of hours of Coilfilter operation desired per week**
5. **Any other pertinent information**

Information on other specialized applications of the Coilfilter, such as for dewatering lime sludge and industrial waste sludges, may be obtained from your Komline-Sanderson representative or from our headquarters in Peapack, New Jersey.

WARRANTY

Manufacturer shall maintain the filter media without charge for a period of 10 years after shipment if the filter unit is operated 40 hours per week, or its adjusted equivalent. The Coilfilter is unconditionally guaranteed to work satisfactorily and filter continuously without clogging or blinding provided that the sludge is conditioned to the following laboratory requirements: Utilizing a No. 2A Buechner funnel and working with 100 CC sample, the sludge is to dewater to a cake of ¼ inch minimum thickness in 100 seconds.

STANDARD SIZES OF KOMLINE-SANDERSON COILFILTERS

Size	Area Sq. Ft.	Size	Area Sq. Ft.
*7′ dia. x 4′ face	85	10′ dia. x 8′ face	250
8′ dia. x 4′ face	100	10′ dia. x 10′ face	300
8′ dia. x 6′ face	150	10′ dia. x 12′ face	350
8′ dia. x 8′ face	200	11.5′ dia. x 12′ face	400
10′ dia. x 6′4″ face	200	11.5′ dia. x 14′ face	500

* Package unit, see photo, page three

Pilot size units also available

There is a Komline-Sanderson representative near you

KOMLINE-SANDERSON ENGINEERING CORPORATION

Peapack, New Jersey

Bulletin No. 102 5-54

Printed in U.S.A.

sometimes possible to provide for raising the liquid ferric chloride by means of compressed air to small storage tanks at a high level from which the chemical can flow by gravity to the sludge conditioning tanks. Control of the rate of flow of the chemical can be accomplished by the use of ordinary pinchcocks.

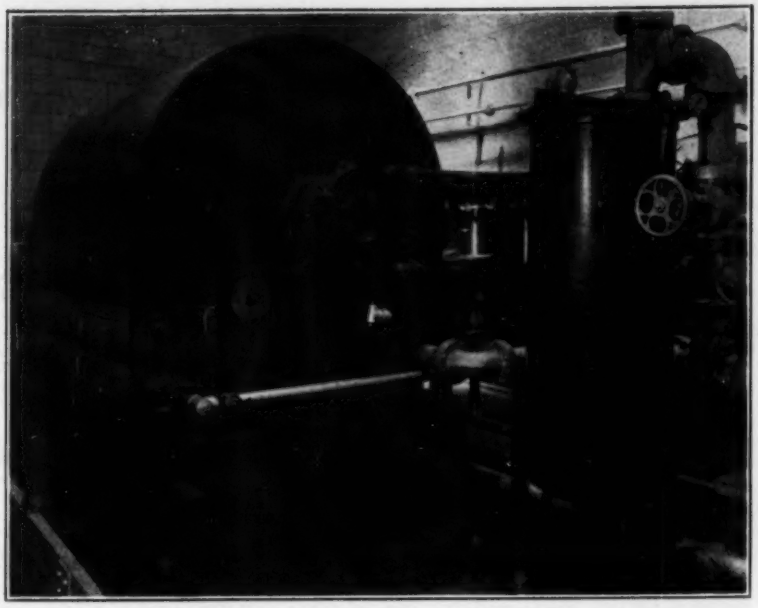
Ferric chloride solution lines may be of hard rubber, rubber-lined pipe, "Uscolite," "Saran," or other suitable acid-resisting materials depending upon the size of pipe and its situation. The valves should be of hard acid-resisting rubber. Plug valves may be of the "Durichlor-Nordstrom" lubricated type as made by the Duriron Co.

Automatic pH Control

It is believed that automatic pH control of ferric chloride addition in connection with conditioning of digested elutriated sludges in the larger plants should result in economical use of ferric chloride under suitable conditions and proper regulation.

Mixers and Conditioning Tanks

It has been demonstrated that the design of mixing tanks for sludge and conditioning chemicals and the point and method of application of chemicals to the sludge in the mixing tank are of considerable importance for economical operation and for obtaining the optimum results at the filters. Elutriated sludge floc forms very rapidly after the addition of the chemical and the floc, once formed, should receive a minimum of disturbance and should be discharged to the filter tank as soon thereafter as is practical.



New Brunswick, N.J.—FEine. Filter, string discharge

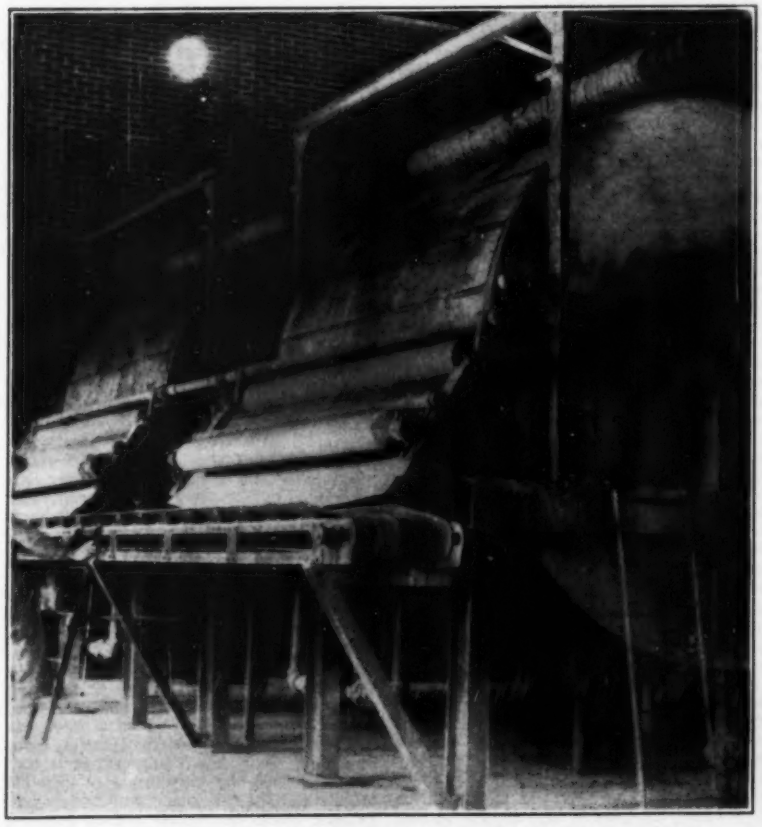
Vacuum Pumps

Wet vacuum pumps such as the Nash Hytor Rotary are used on the smaller filter installations. Vacuum pumps such as Ingersoll-Rand, or Worthington, single-stage, reciprocal dry vacuum pump, are used on the larger installations.

Each pump discharge should be provided with a suitable Burgess or Maxim silencer, of sufficient capacity to effectively silence the exhaust.

Vacuum receiver should be lined with rubber or coated with fibrated asphalt emulsion.

Moisture traps should be provided between the vacuum receivers and the dry vacuum pumps, designed to remove the greatest percent possible of the moisture contained in the air in the vacuum line after it has passed through the vacuum receiver.



York Township, Ontario—Wright String Discharge Filters

Package Units

Several of the manufacturers now offer package units which include the vacuum filter, vacuum pump, blower, filtrate pump, chemical feed equipment and conditioning tank. For filter units up to a size of at least 100 sq. ft., the package units appear to be both practical and economical. The manufacturer in the case of the package units usually assumes responsibility for all of the equipment included therewith. He purchases the appurtenant items of equipment and assembles them in his shop. The assembly therefore requires a minimum of space and minimizes installation problems. This arrangement may be advantageous when the owner is in need of maintenance, repair, and replacement service.

General Acid-Resisting Construction

Equipment which handles ferric chloride conditioned sludge should be of acid-resisting construction. Specifications quite commonly provide for a protective rubber coating $\frac{1}{16}$-in. thick or more, or a coating of fibrated asphalt at least $\frac{1}{8}$ in. thick. The protective coating is customarily applied to the inside of conditioning and mixing tanks, the inside of the filter tank, both ends of the drumheads, the overflow chamber, the agitator blades and arms, the mixing shaft and other parts of the equipment not otherwise suitably protected or of acid-resisting materials.

6—Multiple Hearth Incinerators

A considerable number of multiple hearth sludge incinerators have been installed in the United States, the larger installations being at Detroit, Minneapolis-St. Paul, Cleveland, and Columbus. Representative smaller units include those at New Britain and New Haven, Conn.; Wyandotte, Mich.; Ashland, Piqua, and Barberton, Ohio; and Elmira, N.Y. All of these units were manufactured by the Nichols Engineering & Research Corp.

The Martin multi-zone furnace, presently manufactured by Morse Boulger Destructor Co., has been installed for sludge incineration at Raritan and Rutherford, N.J.; Lansing, Mich., and Wisconsin Rapids, Wis. At present only the Lansing unit is in operation and that for sludge drying. Similar units have been installed for incineration of screenings at Niagara Falls, N.Y., and Milwaukee, Wis.

Design Features

The multiple hearth furnace consists of a cylindrical shell mounted on columns supporting hearths one above the other, the shell lined with a wall of insulation and firebrick.[1] A vertical air-cooled central shaft revolves and turns horizontal arms above each hearth. Teeth attached to these arms continually stoke or rabble the sludge so that it moves progressively downward through the furnace. When designed as an incinerator, hot gases produced by the burning of volatile matter in the sludge, or from supplementary fuel such as oil or gas, pass upwards through the furnace in counter current to the sludge.

Special provisions are advisable if the multiple hearth unit is to provide for both incineration and drying. In addition to the method above described while operating as an incinerator, provision should be made for burning oil or gas over the upper hearths and drawing the hot gases down through the furnace parallel with the travel of the sludge.

The Nichols Multiple Hearth Unit at Dayton, Ohio, has been operated in this manner as a drier since 1939. Digested sludge partially dewatered on sludge-drying beds is further dried to below 8 per cent moisture for sale as fertilizer. Sludge gas burns on the upper hearths and supplies the heat for drying.

At the Toronto Ashbridge's Bay plant two multiple hearth units designed to either incinerate or dry sludge cake, and with a unit capacity to evaporate 12,000 lb. of moisture per hour, have been contracted for. Provision will be made in connection with these units to mix a portion of the dried sludge removed from the bottom hearth with the filter cake before the latter is admitted to the top hearth.

In the following text the writer has summarized operating experiences with multiple hearth units at a number of sewage treatment plants, based upon personal observations, published reports, and comments by the plant operator. The observations presented should not be construed as criticism of designers, manufacturers, or operators. It is the intent to record difficulties which have been experienced, measures taken to improve conditions, and to record operating results so that others facing similar problems may profit thereby.

Detroit

The largest installation of multiple hearth sludge incinerators is at the Detroit sewage treatment plant. There are four units each 22 ft. 9 in. outside diameter with 12 hearths as initially installed and a rated capacity of 330 tons of sludge cake per day. The initial plant included preheaters designed to use the hot gases leaving the incinerator to preheat the air used for combustion. In actual operation, the heat value of the volatiles in the raw sludge under normal conditions of operation have been more than sufficient to support combustion. The operation of the preheaters was not necessary and in fact not desirable.

Operating difficulties with the incinerators at this plant disclosed the necessity for a number of changes in methods, equipment, and appurtenances in order to obtain best results.

In the operation of the Detroit incinerators, it has been found that excessive temperatures caused damage to the equipment and low temperatures caused excessive smoke in which case the burning of large quantities of fuel oil would be required to correct the situation. An important operating feature has been the control of the feed to prevent sudden changes, particularly in the amount of grit and screenings. The problem created by the screenings disposal was in large measure solved by grinding and returning them to the sewage flow. Until recently, it was not practical to dispose of all the grit removed at the plant by incineration. However, changes now being made which include grit storage and feed by means of screw conveyors at a uniform rate from the storage hopper to the conveyor belts discharging to the incinerators should make it practical to incinerate all of the grit with a minimum of operational difficulty.

The initial reciprocating plate feeder on several of the individual incinerator units has been replaced with a variable speed ribbon conveyor and storage bin. This change is reported to have resulted in the elimination of smoke leaks, better and more uniform distribution, and less violent temperature changes.

Some rabble arms are of 12 percent chromium and 12 percent nickel, others are of Nercaloy. The rabble arms of 25 percent chromium and 12 percent nickel must be insulated in the combustion zone in order that they may have reasonable life. Replacement of rabble arms has been greatly reduced since temperatures have been controlled at under 1,600 deg. F. for most of the time. Temperatures are controlled by allowing cool air to enter the furnaces through the hearth doors and by regulation of butterfly dampers in the enlarged section of the ducts ahead of the stacks.

Weightmeter counters have been installed on the control board and also in the filter room to permit closer observation and control of the feed rates.

The linings in the steel stacks through which the vapors from the incinerators are discharged, as initially constructed, were not suitable for the temperatures encountered. Recently corrosion, reportedly caused by acids present in the flu gases, has been a serious problem at the inner faces of incinerator shells, breechings and stacks.

Improvements to incinerator No. 4 have increased its rated capacity to 14 or 14½ tons of sludge cake per hour. The normal working capacity for average monthly production is 12 to 13 tons per hour. This remodeled unit has 11 hearths and enlarged drop holes in the drying and combustion zones. The most important feature improvement to this unit was the additional flue capacity. A large number of lance holes were provided on out hearths to facilitate cleaning and to provide an abundance of fresh air. The latter is reported to be of importance to minimize slagging.

During 1949 the incinerators burned all of the 194,797 tons of filter cake produced at the plant, all of the 1,132 tons of scum removed from sedimentation tanks, and 99.97 percent of the 15,127 tons of grit removed from the grit chambers.

How unit unloadings on multiple hearth incinerators may be best expressed is still a question. The interior diameter, number of hearths, net hearth area, volume for combustion, moisture evaporated, solids destroyed by incineration and ash handled, are important factors. Assuming adequate volume is provided for combustion per unit of hearth area, a unit of loading in terms of pounds of moisture evaporated and solids burned per square foot of net effective hearth area may have significance for purposes of making comparisons of performance between units at various plants. A test load on Detroit incinerator No. 4 resulted in the incineration of 14.31 tons of sludge cake per hour. This cake contained 36.41 percent solids and 52.08 percent volatiles dry basis. The moisture evaporated was about 9.1 tons per hour and the solids incinerated were about 2.7 tons per hour. The net hearth area of this incinerator is 2,500 sq. ft. and the load during this test per square foot of net area per hour was equivalent to 7.28 lb. of water evaporated and 2.16 lb. of solids incinerated, making a total of 9.44 lb. of water and volatiles. Including ash, the rate was 10.5 lb. per sq. ft. per hr.

The ash sluicing pumps have been taken out of a pit and installed at floor level to facilitate their servicing and maintenance.

As first constructed, the Detroit incinerator building was poorly ventilated. In the warmer months, the temperature in the upper operating gallery and under the roof was said to be over 130° F. and there was considerable odor of scorched sludge. Subsequently, four ventilating exhaust fans each of 40,000 cfm. capacity were installed on the roof of the incinerator building to exhaust smoke and gases and to improve conditions within the building.

1 Recent refractory hearths have been cast in place in certain locations within the incinerator units. There are indications that this type of hearth is more satisfactory for some hearths than those made of individual firebrick blocks.

Minneapolis-St. Paul

There are three multiple hearth incinerators at this plant, each 22 ft. 3 in. outside diameter and with eight hearths. Each unit as provided had a rated capacity of 60 tons of dry solids per 24 hr., based on 65 percent moisture in the filter cake and 60 percent combustible matter in the dry solids. A fourth similar unit is under construction. Grit and scum are not burned in the incinerators.

The design assumed that supplementary fuel would be required for incineration of the sludge and that temperatures could be controlled by regulation of the feed of the fuel. However, it was found under practically all conditions of operation an excess of heat existed and no supplementary fuel was required.

Instead of an anticipated maximum temperature of 1,600 deg. F. actual temperatures exceeded 2,200 deg. F.

The preheaters were removed from service with resultant reduction in power and maintenance costs.

It was found that if the feed rate was kept below 1.4 tons of combustibles per incinerator per hour excessive temperatures were practically eliminated. A chart was prepared showing safe rate of feed of filter cake to an incinerator unit for various percentages of solids and combustibles. The operators have found this chart very useful as a guide to operation.

The net hearth area is 2,084 sq. ft. per unit. The nominal capacity of each incinerator unit is equivalent to about 5.4 lb. per hour of moisture evaporated and solids consumed per square foot of net hearth area. On occasion, the units have been reported to satisfactorily handle an overload of approximately 33 percent. On the annual average the units operate at between 85 and 95 percent of the time.

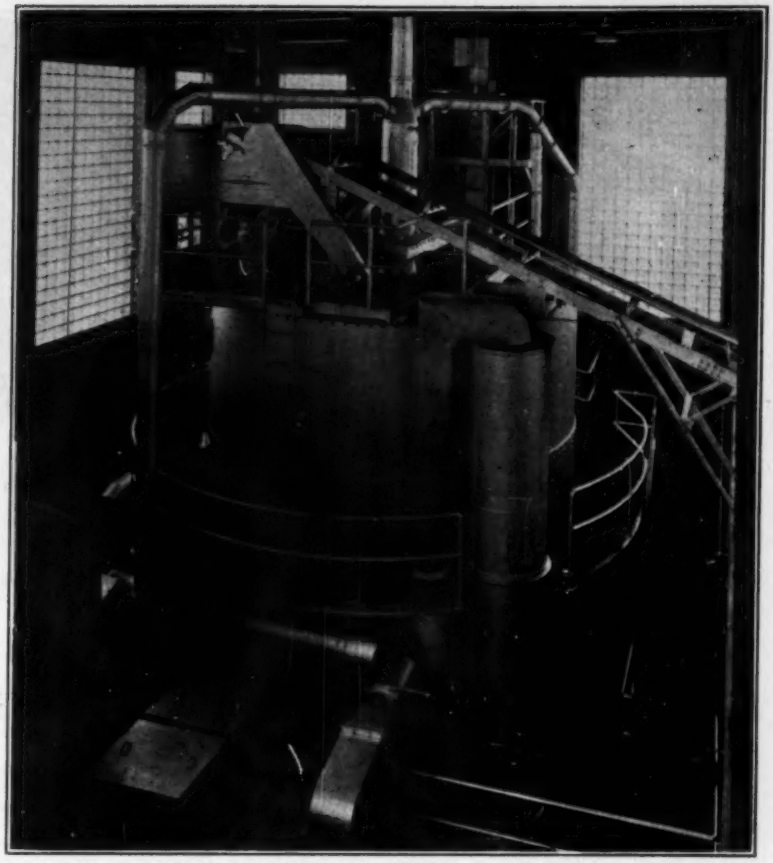
Based on present rated capacity of 1.4 tons of combustibles per incinerator hour, the three incinerators for the past 2 years have averaged approximately 72 percent of capacity. At numerous times during the year individual furnaces may be operated at near capacity for several days at a time.

Maximum temperatures of incinerators are kept below 1,600 deg. F. by operation of an induced-draft fan with variable-speed drive. The fan follows a duct in which water is added as necessary to keep the gas temperature at the fan below 700 deg. F. and protect the fan from damage by overheating. The speed of the fan is controlled from the main operating panel where the hearth temperatures are also recorded.

Ventilation in the incinerator building has been somewhat of a problem. Fixed glass blocks have been replaced by ventilating sash across one end of the building to supplement the three large ventilators placed in the roof. A wall fan has been added to cool a "dead" area in one corner of the incinerator. A similar fan is to be installed over the fourth incinerator now being built.

Cleveland-Southerly Plant

There are four multiple-hearth furnaces at this plant, each unit 18 ft. 9 in. outside diameter with eight hearths. The specified capacity per unit was 100 tons of digested sludge filter cake at 75 percent moisture content per 24-hr. day. In 1940, it was reported that these units could be operated at the average rate of 60 tons per incinerator day. In 1941, the capacity was reported to have been reduced to 50 tons per incinerator day. The inability to obtain design capacity was said to be primarily due to rapid accumulations of fly ash in the preheater passages. It was impossible to clean these passages with the preheaters in operation. On this account, the incinerators suffered from lack of adequate draft and a reduction in capacity.



Lansing, Mich.—Martin Multiple Hearth Incinerator

In 1942, three of the eight preheaters were eliminated, the other five cleaned and repaired, the combustion air ducts were enlarged, a bypass provided around the preheater units, gas boosters were added, and the number of gas burners was increased. Subsequently, the preheaters have been used infrequently. As a result of these changes, the unit incinerator capacity was increased to 80 tons of cake per day in 1943. The rate of operation with cake containing 31.9 percent solids of which 38 percent were volatiles was equivalent to 3.43 lb. of moisture evaporated, 0.60 lb. of volatiles consumed, and 4.03 lb. of moisture and volatiles per square foot net hearth area per hour. The average rate of operation in 1945 was 81.6 tons of cake per day per unit, the cake containing 28.4 percent solids of which 44.3 percent were volatile. The unit load in pounds of moisture evaporated and pounds of volatiles consumed was substantially the same as for the 1943 rated capacity as given above.

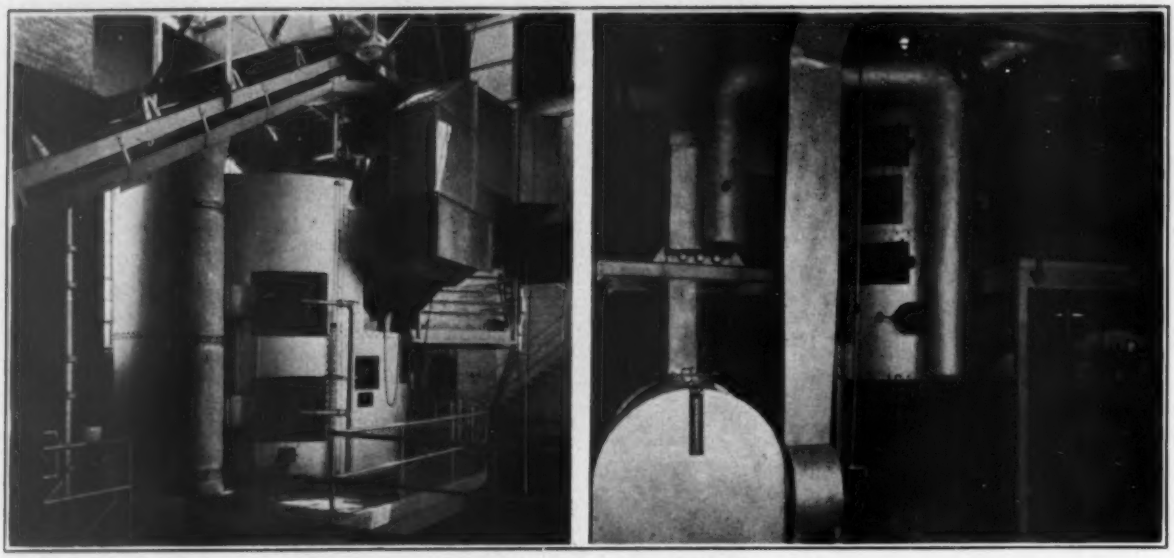
The multiple-hearth units at this plant were designed and initially operated on a somewhat different principle than those handling raw sludge at Detroit and Minneapolis-St. Paul. The top four hearths were drying hearths and are separate from the lower hearths. The hot gases from the combustion hearth beneath the drying hearth did not pass up through the upper hearth, instead they passed through the preheaters and thence up the stack. The gases from the drying hearth at a temperature of 500 deg. F. were passed through the preheaters where it was intended that they be raised to a deodorizing temperature of 1,200 deg. F. and then cooled down to about 500 deg. F. before being discharged to the stack.*

The preheaters are of the steel plate envelope type. As originally installed they were not suitable for the service. Dust and fly ash accumulated in the passages, greatly reducing their capacity and seriously limiting the output of the incinerators. The preheater units could not be cleaned without shutting down the incinerators and the cleaning operations were difficult to perform. In the operating reports, it is stated that the steel envelopes warped even though temperatures were kept within permissible limits. A portion of the preheaters were reported to have burned out during 1941.

Occasional operating difficulties reported include the slowdown or partial interruptions by brick falling out of the hearth, by clinkering of the ash, and by burning out of the bag filters on the ash line.

In 1944 it was reported that considerable trouble was experienced with the warping of the rabble arms and teeth especially on hearths 5 and 6. The pyrocast arms which were used during that period were insulated with Kastset using nichrome wire as reinforcement to prevent warping. One ring of the refractory was removed from hearth 5. Eventually rabble arms on the lower or combustion hearths containing 25 percent

*In 1942, after the incinerators were revamped, the method of burning sludge was on the same principle as at Detroit and Minneapolis-St. Paul.



Two examples of small Nichols Multiple Hearth Incinerators
Wyandotte, Mich. (on left) and Middletown, Conn. (on right)

chrome and 12 percent nickel were found to be satisfactory.

Theoretically all the vapors and gases discharged from the stack have passed through deodorizing temperatures. The stack extends only a few feet above the roof line and the wind currents from the bluff above the plant drive the vapors down to ground level. Observers have reported that at times a decided odor of scorched sludge has been detected in the vapors from the stack.

Ventilation in the incinerator building during the summer months has been reported as unsatisfactory. During this period, there is a tendency for the operators to spend as much time as possible out of doors.

Columbus, Ohio

The multiple-hearth incinerator at Columbus has an outside diameter of 16 ft. 9 in. and has six hearths. It was designed to incinerate 80 tons per day of digested sludge containing 75 percent moisture and 12½ percent combustible matter wet basis. It is reported to have a capacity to burn 50 tons per day of digested sludge filter cake at 75 percent moisture and 50 percent volatiles dry basis. The net hearth area is 845 sq. ft. The reported unit capacity is equivalent to 3.70 lb. of moisture evaporated, 0.56 lb. of solids consumed, and 4.26 lb. of moisture and volatiles per square foot of net hearth area per hour. For 1950 the average feed rate was 1.7 tons per hour of cake containing 28.8 percent solids of which 38.4 percent were volatiles. This is equivalent to 2.87 lb. moisture evaporated, 0.43 lb. of solids consumed, and 3.32 lb. of moisture and volatiles per sq. ft. of net hearth area per hour.

Operating reports indicate that it is necessary to shut down this unit for 15 percent of the time in order to make repairs such as renewing rabble teeth and replacement of rabble arms.

An air preheater of the sectional plate type was originally installed with 2,484 sq. ft. of heating surface. All of the equipment within the preheater was removed after the incinerator was placed in operation and the unit lined with firebrick so as to serve as a flue. The preheater became so caked up that it limited the passage of hot gases and greatly restricted the incinerator capacity.

As originally installed, all of the rabble teeth on the arms over the upper hearth were directed so as to move the sludge toward the outer edge. Two rabble teeth on each arm have been reversed so as to hold back some of the sludge cake and increase the drying time. Observations have shown an unusually deep accumulation of sludge cake, well broken up and well mixed as a result of this minor change. Ordinarily the top two hearths in this unit are drying hearths. The third and fourth hearths are combustion hearths and the fifth and sixth are for completion of combustion and cooling off of the ash.

Some of the heat from the exhaust gases is reclaimed under low-pressure steam boilers and used for heating the plant buildings and the sludge digestion tanks.

As in a number of other plants employing sluicing, ash handling has given considerable trouble at the Columbus plant. Lime is used for sludge conditioning and has accumulated as $CaCO_3$ in the ash hopper and in the ash lines to an extent requiring considerable work for removal. Clinkers have accumulated in the ash tanks and have been difficult to remove. This experience points to the desirability of having a quick-opening gate between the lower hearth and the ash hopper so that ash can be stored on the lower hearth while the work of removing clinkers and lime encrustations in the ash tank is carried on. Also clinkers find their way into the slurry pump, causing serious cutting of the impeller and rubber lining.

Difficulties with calcification in the wet ash discharge lines have led at Columbus to serious consideration of discharging the ash in a dry condition. The operators are of the opinion that if wet ash from lime conditioning sludge must be pumped, ample provision should be provided for removal of encrustation and the pipeline should be readily accessible for cleaning operations.

The incinerator chimney at Columbus includes a lined steel stack manufactured by Prat-Daniel and designed for a head induced by a cold air fan which acts as an injector. Cold air is forced into the stack near the restricted section so as to create a draft of up to 2 in. in the gases from the incinerator and boilers. The cold air, induced-draft fan has a variable speed drive and the draft can be governed within desirable limits. This arrangement eliminates a hot air induced-draft fan and provides an excellent means for regulation of incinerator operation.

Ashland, Ohio

The results of incineration of liquid sludge at Ashland, Ohio in a multiple-hearth unit have been reported by Laboon.* This unit is 9 ft. 3 in. outside diameter. As initially built it had four hearths. It was found advisable to add two hearths in order to incinerate concentrated liquid sludge in this unit.

The results of 6 days of tests made during September and November, 1947 have been given by Laboon. The unit was operated 140.33 hours, evaporated 146,499 lb. of moisture, consumed 18,473 lb. of volatiles, and passed 6,130 lb. of ash during the period. The unit rate of operation was about 5.39 lb. of moisture evaporated and 0.68 lb. of volatiles consumed per square foot net hearth area per hour.

Summary

On the basis of operating experience some of the features of design, construction, and operation of multiple-hearth furnaces to be used for drving and incinerating sewage sludge requiring particular care follow:

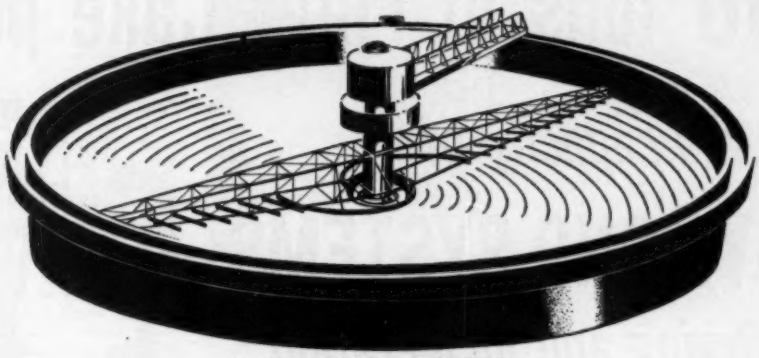
1. There should be ample capacity to discharge the products of drying and combustion. The drop holes should be of such size as to pass the hot gases upward and the sludge downward without clogging and undue loss of head.

2. Preheaters are not necessary for economical incineration of raw sludge cake.

3. Preheaters if provided should be a type which can be cleaned with facility. An ample bypass should be provided for each preheater unit so that it may be cleaned while the incinerator unit remains in opera-

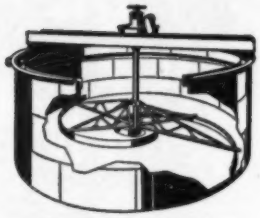
*John F. Laboon, Sewage Works Engineering, 1949, p. 64.

HARDINGE SANITATION EQUIPMENT



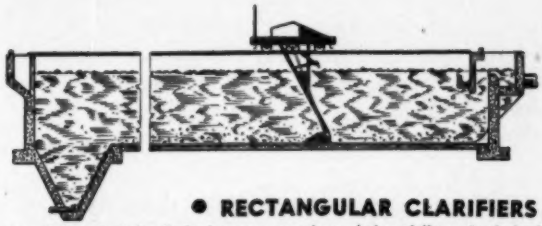
• CIRCULAR CLARIFIERS

Hardinge Circular Clarifiers are available in sizes up to 200' diameter, either center-column or beam supported for steel, concrete, wood or tile tanks. Sludge scrapers remove settled solids rapidly through central underflow discharge. Bulletin 35-C-15.



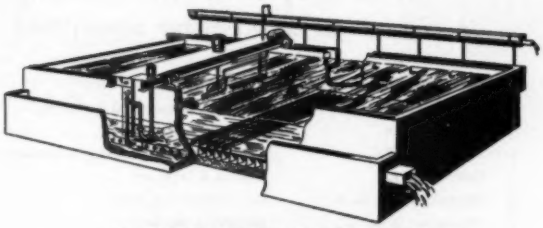
• THICKENERS

For removal of fine suspended solids from supply water, waste water and sewage. "Auto-Raise" mechanism prevents scraper breakage. Bulletin AH-442-15.



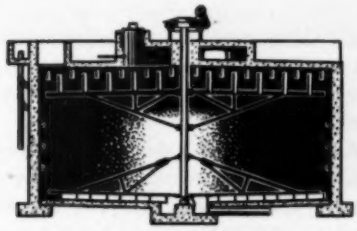
• RECTANGULAR CLARIFIERS

Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. A traveling scraper and skimmer carriage removes settled solids from the tank bottom and scum from the top. Bulletin 35-C-15.



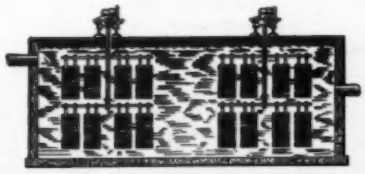
• AUTOMATIC BACKWASH RAPID SAND FILTERS

For high removal of non-settling or slow settling suspended matter. Self-cleaning sand bed. No shut-down necessary for backwashing. Traveling backwash mechanism. Bulletin 44-15.



• DIGESTERS

Sludge scrapers and scum breaker arms prevent scum accumulation, insure uniform gas production. Emit a dense digested sludge. Bulletin 35-C-15.



• FLOCCULATING UNITS

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• HYDRO-CLASSIFIERS

A large-volume classifier for rapid separation of coarse and fine suspended solids. Frequently used for by-product recovery from waste water. Bulletin 39-B-15.

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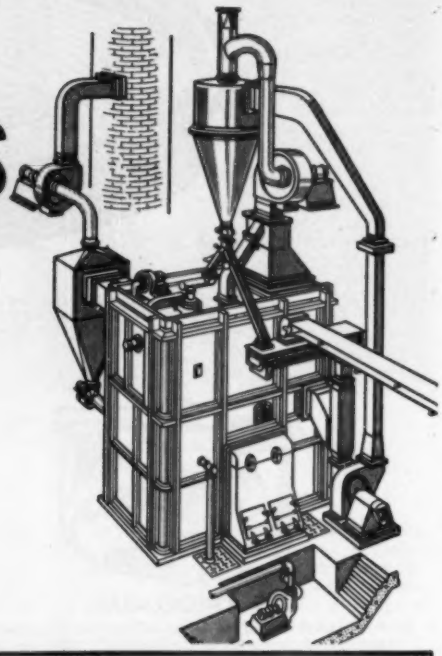

The most widely used heat method of sewage sludge disposal is the C-E Raymond System of Flash Drying and Incineration. Total daily capacity of C-E Raymond Systems installed, under construction or on order is more than 10,000 tons of filter cake, based on 24-hour operation . . .

This is nearly 50% more than the total of all other heat methods.

One important reason for this marked preference for the C-E Raymond System is that it is the most widely proven method that permits the flash drying of sludge to a saleable fertilizer or its incineration to a sterile ash . . . in either case with the deodorization of stack gases if desired. No other method offers this practical flexibility.

Another reason is that the C-E Raymond System has been service-proved in actual use in communities of every size—ranging in equivalent populations from 6,000 to 3,600,000 . . . and located in all parts of the country from coast to coast.

Like the communities listed at the right, you, too, can plan to end your sludge disposal problems by the proven C-E Raymond System. For full information, just get in touch with the C-E Raymond office nearest you. A C-E specialist will be glad to help you.

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Bloomsburg, Pa.	Gannet, Fleming, Corddry & Carpenter
Camden, N. J.	Havens & Emerson
Chicago, Ill. (W. So.W.)	City Engineering Dept.
Edgewater, N. J.	McClave & McClave
Fond du Lac, Wis.	Jerry Donohue Engrg. Co.
Galveston, Texas	Joe J. Rady & Co.
Houston, Texas	Greeley and Hansen
Lansing, Mich.	Drury, McNamee and Porter
Los Angeles, Cal.	Metcalf and Eddy
Miami, Fla.	Metcalf and Eddy
San Diego, Cal.	Frank Currie
San Francisco, Cal.	Clyde C. Kennedy
Schenectady, N. Y.	Havens and Emerson
Sheboygan, Wis.	Jerry Donohue Engrg. Co.
Washington, D. C.	Greeley and Hansen
Waterbury, Conn.	Malcolm Pirnie
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ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

tion. Preheaters of the closely spaced plate type are not satisfactory for this type of service.

4. Adequate means should be provided to permit an even rate of feed to the incinerator unit, particularly of moisture and combustibles. The rate of feeding relatively low volatile grit and relatively high volatile scum should be subject to fairly close control.

5. The rabble arms and teeth in the combustion hearths should be of heat resisting alloys. The central shaft at combustion hearths should be suitably insulated. A liberal allowance should be made as to the extent to which combustion may proceed above and below the theoretical average combustion zone.

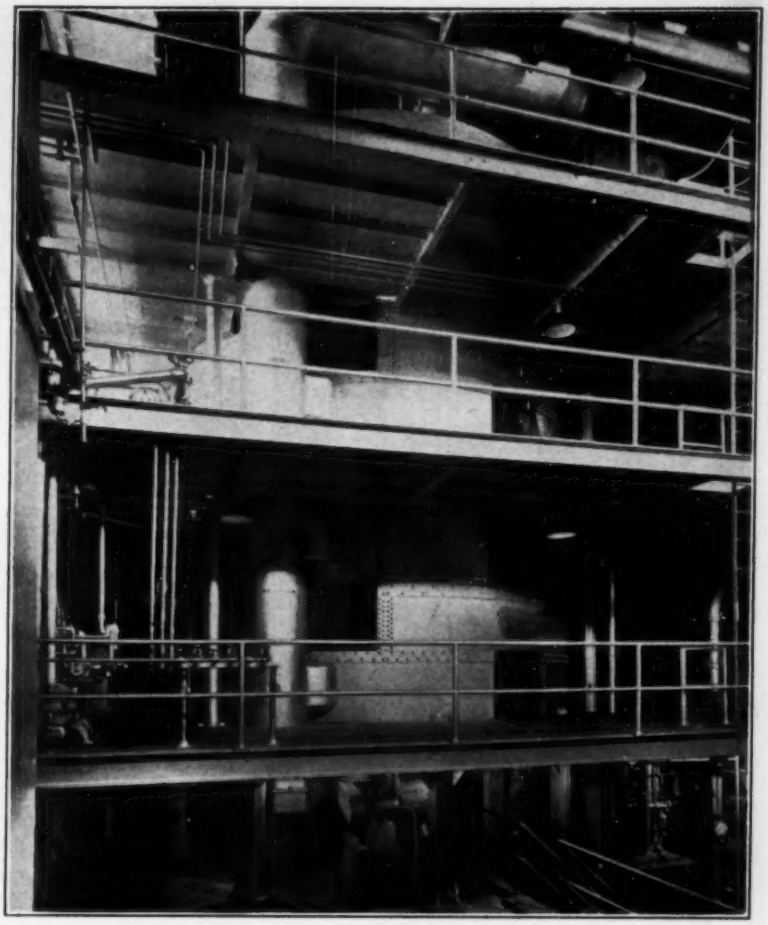
6. Consideration should be given to the protection of the incinerator stack against high temperature gases under certain conditions and against the corrosive action of acid and moisture under certain other conditions.

7. The ash system should be designed for ready access. A shutoff gate is desirable between the lower hearth and the ash system so that the latter may be worked on while the incinerator unit remains in operation. Ash slurry discharge lines should be designed so that stoppages may be cleaned or encrustations removed. Duplicate ash discharge lines may be required in order to make shut down unnecessary.

8. Adequate ventilation should be provided in sludge drying and incinerator buildings so that working conditions are not too uncomfortable.

Acknowledgement

Acknowledgement is gratefully made for data supplied by Fred H. Burley, Engineer of Sewage Treatment at Detroit; Kerwin L. Mick, Chief Engineer and Superintendent of the Minneapolis-St. Paul plant; George E. Flower, Commissioner of Sewage Disposal at Cleveland; James H. Blodgett, Superintendent of Sewage Treatment Works at Columbus; and Robert W. Rowen, Vice President of Nichols Engineering & Research Corporation.



Minneapolis-St. Paul Sanitary District Incinerator

7—Flash Drying and Incineration

The following article differs from others in this series in that it deals only with the product of one manufacturer although the preceding article covered for the most part only the multiple hearth sludge drying and incinerating equipment as manufactured by Nichols Engineering & Research Corp. As heretofore in these articles it is the intent to record operating experiences and measures taken to improve the equipment and its maintenance so that others facing similar problems may profit thereby.

History

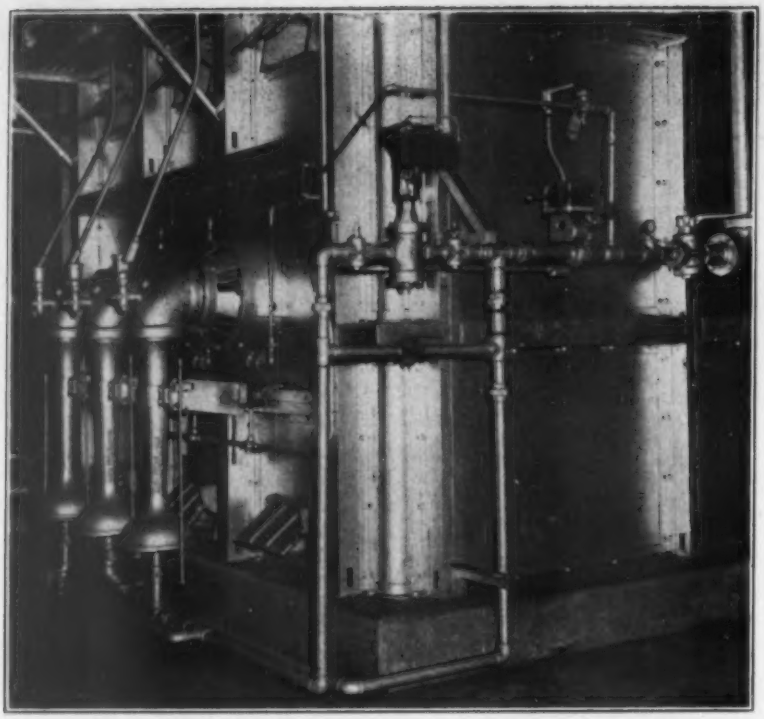
The C-E Raymond system of flash drying and/or incineration was first undertaken on a large scale at the West Side Plant of the Chicago Sanitary District in 1935. Subsequently, numerous installations have been made including other plants at Chicago and at Neenah-Menasha, Wis. (1937); Buffalo, N.Y. (1938); Springfield, Mass. (1940); Cuyahoga Falls, Ohio (1940); Duluth, Minn. (1941); Manitowoc, Wis. (1941); San Diego, Calif. (1943); Battle Creek, Mich. (1944); Sheboygan, Wis. (1946); Houston, Texas (1950); and Los Angeles, Calif. (1950). Large installations not yet under operation include those at Baltimore, Md.; San Francisco, Calif.; Waterbury, Conn.; Schenectady, N.Y.; Bethlehem, Penn.; and Washington, D.C.

In the C-E Raymond system, filter cake is mechanically mixed with a portion of dry material in a mixer of the pugmill type, and then violently agitated in the presence of hot gases in a cage mill. The mixture discharges into a cyclone collector. The sludge at about 10 percent moisture separates in the cyclone from the hot vapors and gases. A portion of the dry material is returned to the process and the remainder may be drawn off and disposed of in the dry form or burned in the furnace which supplies the hot gases for the cage mill.

This type of unit is also used for fertilizer production or for incineration in connection with standard garbage and refuse incinerators. The units at Watervliet, N.Y.; and Stamford, Conn., are of this type.

Buffalo

At Buffalo, N.Y., there are three flash drying units each designed to evaporate 5,833 lb. of moisture per hour with associated furnaces for incineration of the dried



Houston, Texas—Two units for activated sludge

sludge. Soon after these units were started in operation, it was found that the sewage sludge contained a substantial proportion of sand which proved to be very abrasive. Points of wear included mixers, the cage mills, the separating cyclones and in the fuel pipeline which transported the dried sludge from the flash drying system to the burners. Operating experiences have been described in the annual reports and by Velzy, Johnson and Symons.†

Drying towers were provided where hot gases from the furnaces are mixed with sludge before passing to the cage mill. These were lined initially with stainless steel plates which became distorted after a period of operation. Replacement of the buckled liners with a ceramic material poured in a wooden form proved to be a satisfactory solution to this problem.

The dry sludge cyclones were originally equipped with mild steel replaceable liners. It developed at Buffalo and elsewhere that this method of lining was uneconomical. The manufacturers made an intensive study of the problem and arrived at the conclusion that a gunite lining, consisting of trap rock and lumnite cement, was a satisfactory and economical protection for the interior of the sludge cyclones. Several of the cyclones at Buffalo have been lined with a ceramic known as "packing house floor tile," or with quarry tile.

The solution for the wear on the paddles in the mixers appears to be a paddle with easily replaceable abrasion resisting tip.

Changes made to one cage mill at Buffalo illustrates current standard practice. In order to provide for more economical maintenance, the housing was built to allow for rapid dismantling and provision made to pull the agitator mill out on rails for inspection or adjustment. The need for this was demonstrated as the rods on the rotor and stator were subjected to severe abrasion. As first rebuilt, the rods in the cage mill were protected with high manganese steel but these were expensive and wore out rapidly. A second development using a double, extra heavy, 1¼-in. steel pipe sleeve over a ¾-in. gave more economical results. With further experience, it is indicated that the most economical design is to supply 0.40 carbon steel bars and to build them up with stellite or other hard facing material as wear occurs.

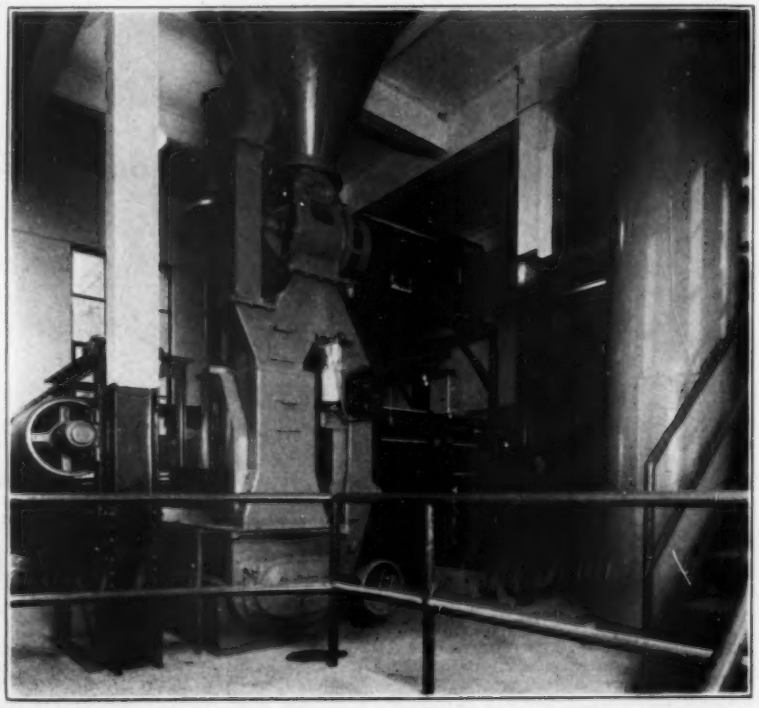
The fuel pipelines initially installed at Buffalo have been removed and have not been used subsequently at other plants. The standard type of sludge feeder now consists of a duct from the drying cyclone to a screw conveyor which feeds the sludge burner.

The induced draft fans as originally installed were on the dirty air side of the ash cyclone. The fans wore rapidly and repairs and replacements were difficult to make. When these fans were moved to the clean air side of the ash cyclones, the wear due to abrasion by sand in the ash was largely eliminated.

The initial installation of pneumatic equipment for ash removal included a cyclone bag filter and vacuum pump. With the temperature of the ash at 1,100-1,113 deg. F., the bags in the filter burned out and the vacuum pump became plugged with ash, a problem solved by installing a second cyclone in place of the bag filter and a steam ejector in place of the vacuum pump.

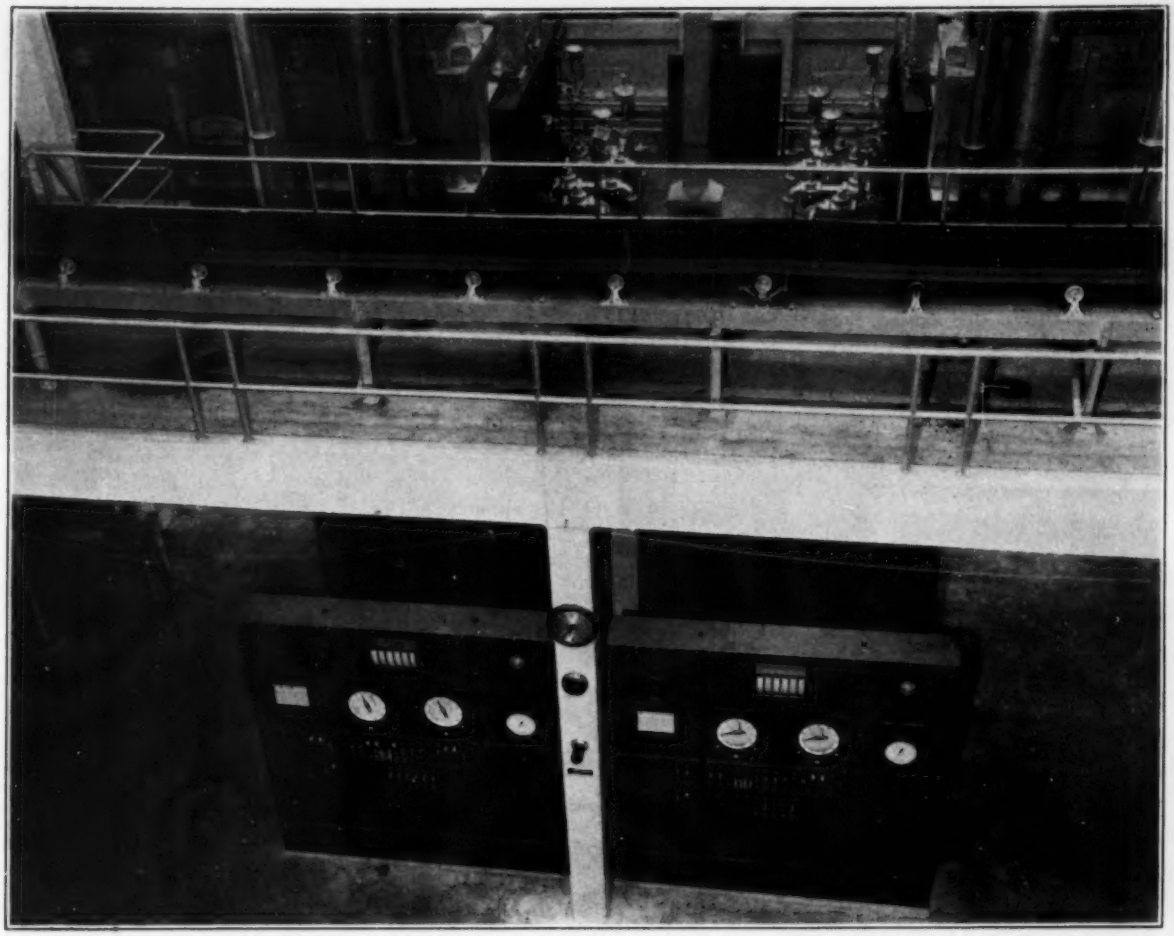
Springfield, Mass.

The unit at Springfield has a rated capacity of 10.5 tons per day dry weight of digested sludge solids per 24 hr. when drying sludge cake containing 67.5 per cent moisture with 50 per cent volatile dry basis. During the 10 years 1941-1950, inclusive, the unit was operated on the average of 1,411 hr. per year or approximately 5.6 hr. per work day for a 5-day week, while handling the total sludge production. The average moisture evaporated was approximately 750 lb. per hour of operation. The auxiliary fuel in the form of sludge gas used for burning the sludge amounted to about 650 cu.ft. per 1,000 lb. of moisture



Stamford, Conn.—Flash drying system in connection with garbage and refuse incineration

†Sewage Works Journal, September 1940.



Los Angeles, Calif.—Hyperion Plant has four units for handling activated sludge

evaporated. This is reported for conditions in which there is an abundance of sludge gas at the plant and where it is not necessary to take particular care in the conservation of fuel at the incinerator.

During the years 1943 and 1944, the sludge was dried for fertilizer but in other years the market was not favorable enough to warrant drying operations and expense.

As in the case with Buffalo, the drying cyclones were initially lined with steel plates. They have subsequently been relined with a mortar of lumnite cement and trap rock. The life of the paddles in the sludge mixers has been extended by adding a facing of abrasion resisting materials by means of electric welding.

John P. McDonald, sewage treatment plant engineer, at Springfield, reports complete satisfaction with the installation after 10 years of operation. He states one of the advantages of this type of equipment is the facility with which it can be started up without undue delay in preheating or without burning fuel during nightly or weekend shut-downs. The practice of burning during the day shift only and with no heating during the standby period has not resulted in evident damage to the furnaces.

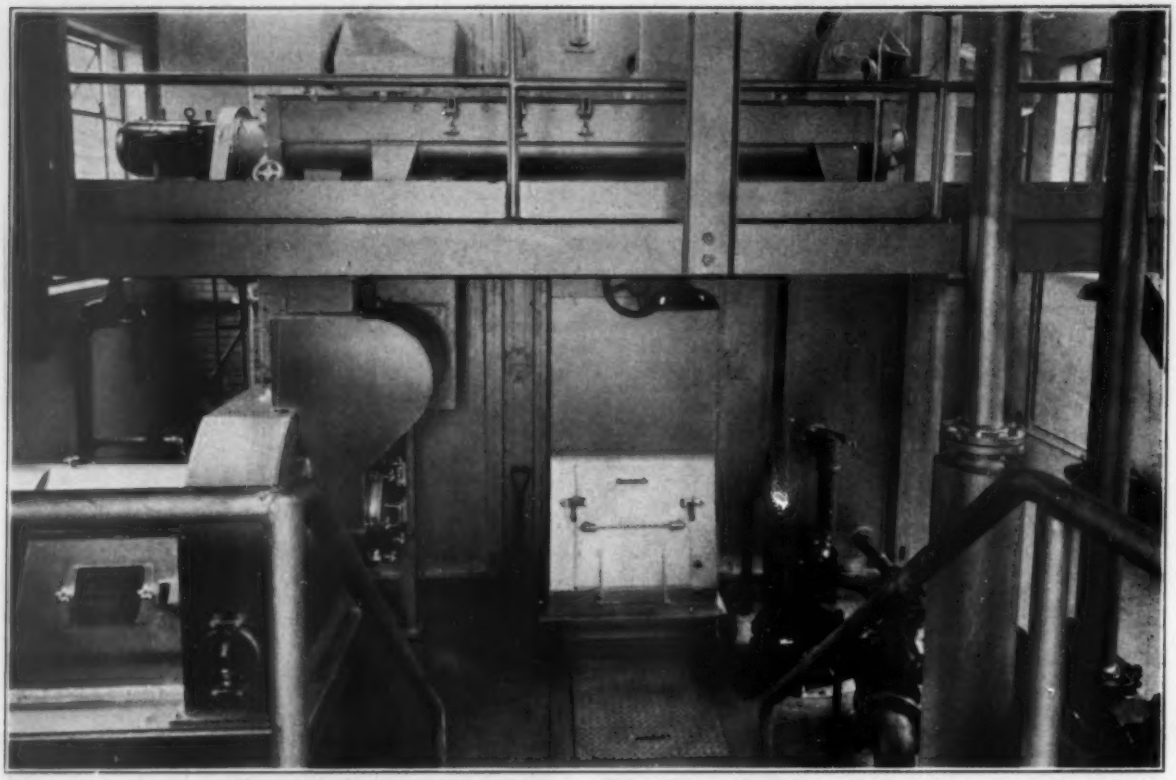
San Diego, Calif.

The first C-E Raymond unit at the San Diego plant was placed in operation during 1943. This unit has a rated capacity to evaporate 3,500 lb. of water per hour. Enlargements to the plant which were commenced in 1948 included an additional flash dryer with a capacity of 5,000 lb. of water evaporated per hour.

The experiences in operation at this plant due to wear from quantities of sand in the sludge removed have been somewhat similar to those at Buffalo.

One of the problems that has been peculiar to the San Diego plant has been the prevention of explosions which would occur from time to time during the shutdown period. In accordance with the manufacturers' recommendations, facilities have been provided to permit flooding the system with steam during shutting down procedure or at times of power failure. The same protection can be afforded by the injection of water through fog nozzles. The manufacturers have commented that this system, in common with all flash drying systems, is equipped with a relief vent on top of the cyclone. They state that this relief vent will safely relieve explosions of any kind and without any danger to the operating staff. This latter is evidenced by the fact that over 10 to 12 years' experience with operation of these plants there is no reported case of damage to the equipment or injury to an operator from such source. However, it is reported that these "puffs" are demoralizing to operating personnel and the manufacturers state that provisions for injection of steam or water is a simple and convenient way of rapidly cooling down the system without damage to the equipment or furnace and is a very desirable convenience. At San Diego, the injection is made at the entrance to the dryer cyclone and cage mill.

The new installation includes a reinforced concrete brick-lined exhaust tunnel and 150-ft. stack for removal of dryer gases. There have been several fires in the tunnel and lower part of the stack. It appears that the operation of water sprays throughout the length of the tunnel and at the bottom of the stack has eliminated this difficulty. It is reported that the trouble in the tunnel was due to build-up of grease from ¼ to ¼ in. in thickness. This matter of grease in the sludge is an ever increasing problem in the operation of sludge handling and disposal units since the end of World War II. It is generally believed to be the result of the increasingly wide use of detergents. The manufacturers report that this trouble is not confined to any one plant or one location but that it is rather general. A grease content in the dry sludge up to approximately 8 percent will give no trouble. However, when this percentage is substantially exceeded, the very low temperature volatile fractions of the grease are distilled off and will condense on any cool surface. If not continuously removed, it may be ignited at some time during the period of the shutdown of the system. To preclude such the safe thing to do is to clean this part of the equipment either continuously by the



Cuyahoga Falls, Ohio—Small flash drying and incineration unit for handling raw sludge

use of water sprays or periodically by scraping.

A further reference to this problem of grease accumulation is given in the discussion of the operation of the Los Angeles plant.

Eric V. Quartly, superintendent of the San Diego sewage treatment plant, reports that while many operating problems have been experienced with the flash dryers during past years, he does not wish to convey the impression they are unsatisfactory for the purposes intended. On the contrary, he states these units are giving excellent service at the present time.

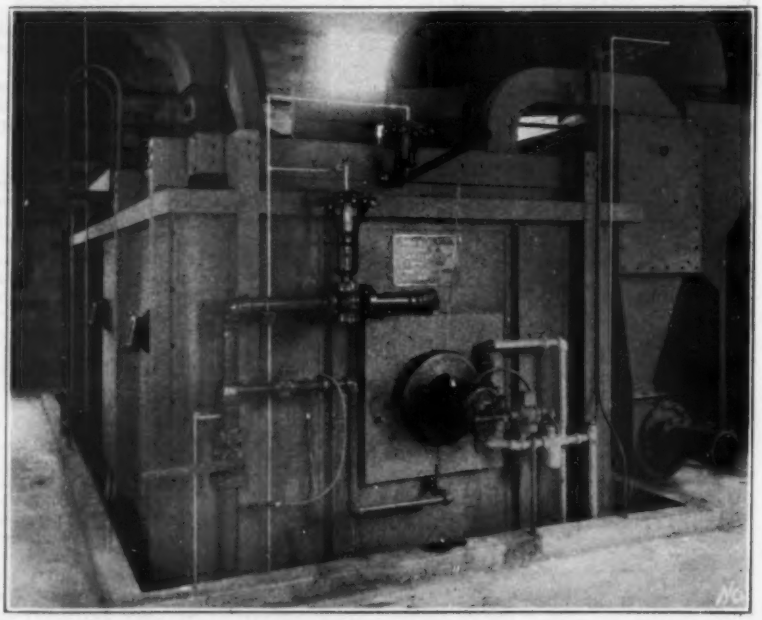
Los Angeles

The flash drying and incinerating equipment at the Los Angeles Hyperion plant includes four units each having a capacity to evaporate 22,500 lb. of moisture per hour from sludge cake containing 25 percent solids. Each unit was specified to be capable of incinerating all or any portion of the material dried by it.

The equipment was first placed in operation during August, 1950. In a recent operational test conducted by the City, the average evaporation was 22,280 lb. of water per hour while producing fertilizer at the rate of 8,670 lb. per hour with an average filter cake load of 31,700 lb. per hour. The dryer inlet temperature was 1,112 deg. F. as compared with a design temperature of 1,300 deg. F. It is possible that if the design temperature was maintained at the dryer inlet, the evaporative capacity would be well in excess of the guaranteed figure.

During the month of May, 1951, the dryers reduced all of the filter cake produced at the plant to fertilizer amounting to 4,000,000 lb. for the month (moisture content 7 percent). Since the dryers were operated for only 23 percent of the time, there was no need to operate them at their rated capacity. The average moisture evaporated was 14,550 lb. per dryer. The dryer units at this plant have indicated that they can take care of all of the sludge produced on a design basis and with one spare unit.

As at the San Diego plant, there is some evidence of accumulation of grease which appears to have occurred when the digested sludge contained a reported average of 15 percent grease. Recently, the temperatures



Sheboygan, Wis.—Flash drying system for producing digested sludge fertilizer

Springfield, Mass.—Drying and incineration units for digested sludge

within the digestion tanks have been raised from an average below 90 deg. to about 95 deg. At the higher temperature, it appears that the grease content in the digested sludge will average approximately 5 percent. It is hoped that this will eliminate in large measure the grease problem on the walls of the flash drying equipment.

Summary

GENERAL. Equipment handling sewage sludge should be so designed as to resist wear from the abrasive particles contained therein. Parts subject to wear should be readily replaceable or provision made to build up the worn parts with abrasive resisting materials.

PREHEATERS. Adequate provision should be made for cleaning, maintenance, and repair of preheaters in connection with flash drying furnaces.

MIXERS. The mixers designed for mixing dried sewage with wet sludge cake should have abrasive and corrosion-resisting liner plates. The paddles should be of meehanite or other steel alloy capable of resistance to wear at high temperatures. Shafts and paddles should be readily replaceable and it is desirable to supply the paddles with easily replaceable abrasive resisting tips.

CAGE MILLS. The inlent end of the cage mill should be lined with a corrosion-resisting alloy. The cage mill should be of quick-opening design in which the rotor and pedestal may be rolled back on a track thus facilitating the replacement of liner plates and the replacement of cage bars.

INDUCED DRAFT FANS. These fans should be installed on the clean air side of the ash cyclones where practical.

DUCTS. The ducts and pipes carrying sludge in suspension should be fabricated in easily removable sections. The bends should be provided with removable wear backs lined with abrasive resisting material such as chrome ore.

PURGING SYSTEM. A suitable system of water or steam purging for prevention of explosions in the system should be provided.

CYCLONE SEPARATORS. A lining is required which will resist abrasion. A 2-in. gunite mixture of lumnite cement and trap rock appears to be suitable for this purpose.

STACKS. It appears desirable to line chimneys taking the discharge from the flash dryers and incinerator with firebrick for at least the lower ⅓ of their height. Consideration should be given to the fact that occasional high temperatures may occur in the operation of incineration equipment.

FLY ASH REMOVAL. Fly ash may create a serious problem in the gas discharged from the fly-ash drying systems unless appropriate means are provided for its removal. It has become increasingly necessary in the case of new installations to comply with stringent fire, smoke and air pollution ordinances. Enlarged ducts, settling chambers or inertia separators seldom would prove to be satisfactory.

Mechanical dust removal equipment such as the Multiclone type as manufactured by Western Precipitation Corp. or the fly ash collectors using the Van Torgeren system as manufactured by Buell Engineering Co., or the Thermix Controlled Multi-Clone type as manufactured by the Prat-Daniel Corp. usually afford satisfactory results for this service. However, in some cases, a higher degree of treatment must be provided for the removal of fly ash, such as electrostatic precipitation.

This latter type of equipment must be carefully designed to permit access for cleaning. If continuously high efficient removal of fly ash particles and smoke is required, sufficient units for fly ash removal must be provided so that one unit may be taken out for repair and maintenance.

Acknowledgment

Acknowledgment is gratefully made for data supplied by John P. McDonald, Sewage Treatment Plant Engineer, Springfield, Mass.; Eric V. Quartly, Superintendent, Sewage Treatment Works, San Diego, California, and to C. W. Gordon, Manager, Flash Dryer Division, Combustion Engineering-Superheater, Inc.

TEN PACKING "DONT'S" WORTH HEEDING

It is well known that "don'ts" are often more effective than "do's," so here are some suggestions and warnings arranged as "don'ts" that are based on many years of practical experience. They will be found useful in connection with the selection and installation of packings. To follow them may mean freedom from trouble that would occur when even the best obtainable packing is improperly installed.

1—DON'T fail to make clear what the packing is to pack. In other words, with what will the packing make contact?

2—DON'T guess at a size, diameter, width or height when ordering packings. Many failures have resulted from small errors in dimensions.

3—DON'T allow too little or too much clearance between follower plate and inside cup wall, or any metal parts behind any upright leather wall; 1/16 to 3/32 inch on each side, depending on size of packing, is usually recommended.

4—DON'T doctor packing lips with a pocket knife or file, or batter lip in installing. A rounded lip destroys the seal. Packings can be softened by soaking in warm water if necessary.

5—DON'T apply cup packings with flange too high for clearance at the head of the cylinder. Keep systems clean so sediment will not collect in cylinders and wear the packing.

6—DON'T apply cup packings to end of plunger which is badly worn; pressure will force the packing down into clearance between plunger and clyinder. Leather washers cut from old cup packings can be made to reline such equipment to proper dimensions.

7—DON'T apply "U" packings where plungers are worn without reinforcing under heel with leather cushion rings.

8—DON'T look for long service on scored plungers or in scored cylinders; resurface or reline such equipment to proper dimensions.

9—DON'T allow water to corrode cylinder walls, plungers or rods. Use an anti-rust agent that will prevent this and that will act as an effective lubricant.

10—DON'T squeeze hemp or fabric filled "U" packings in glands where such packings are to replace solid section compression packings; set glands up to point where "U" packaings are free to function properly.

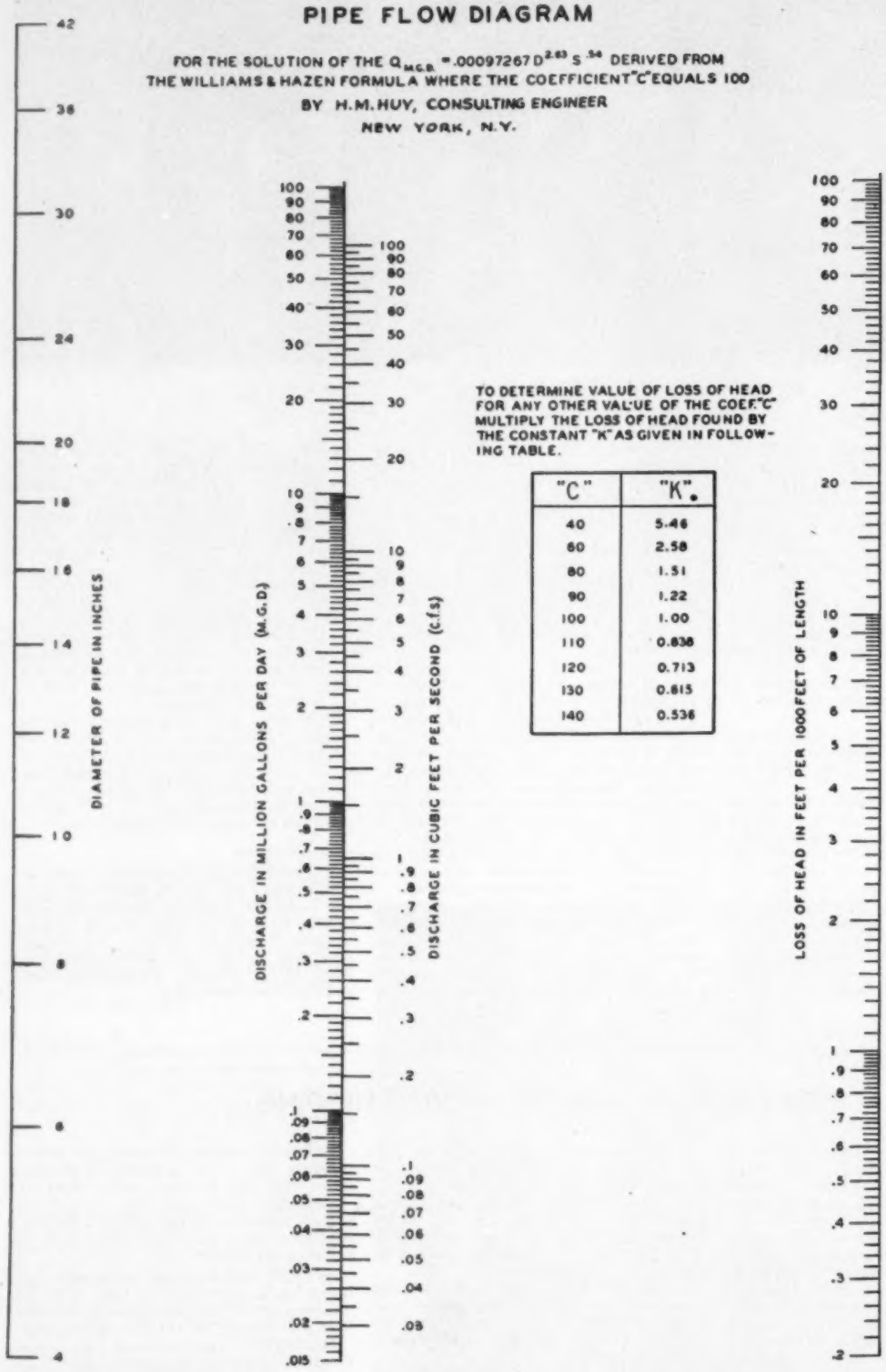
Contributed by *W. F. Schaphorst*, M. E., Newark, N.J.

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097267\, D^{2.63}\, S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H.M. HUY, CONSULTING ENGINEER

NEW YORK, N.Y.



TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

"C"	"K".
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

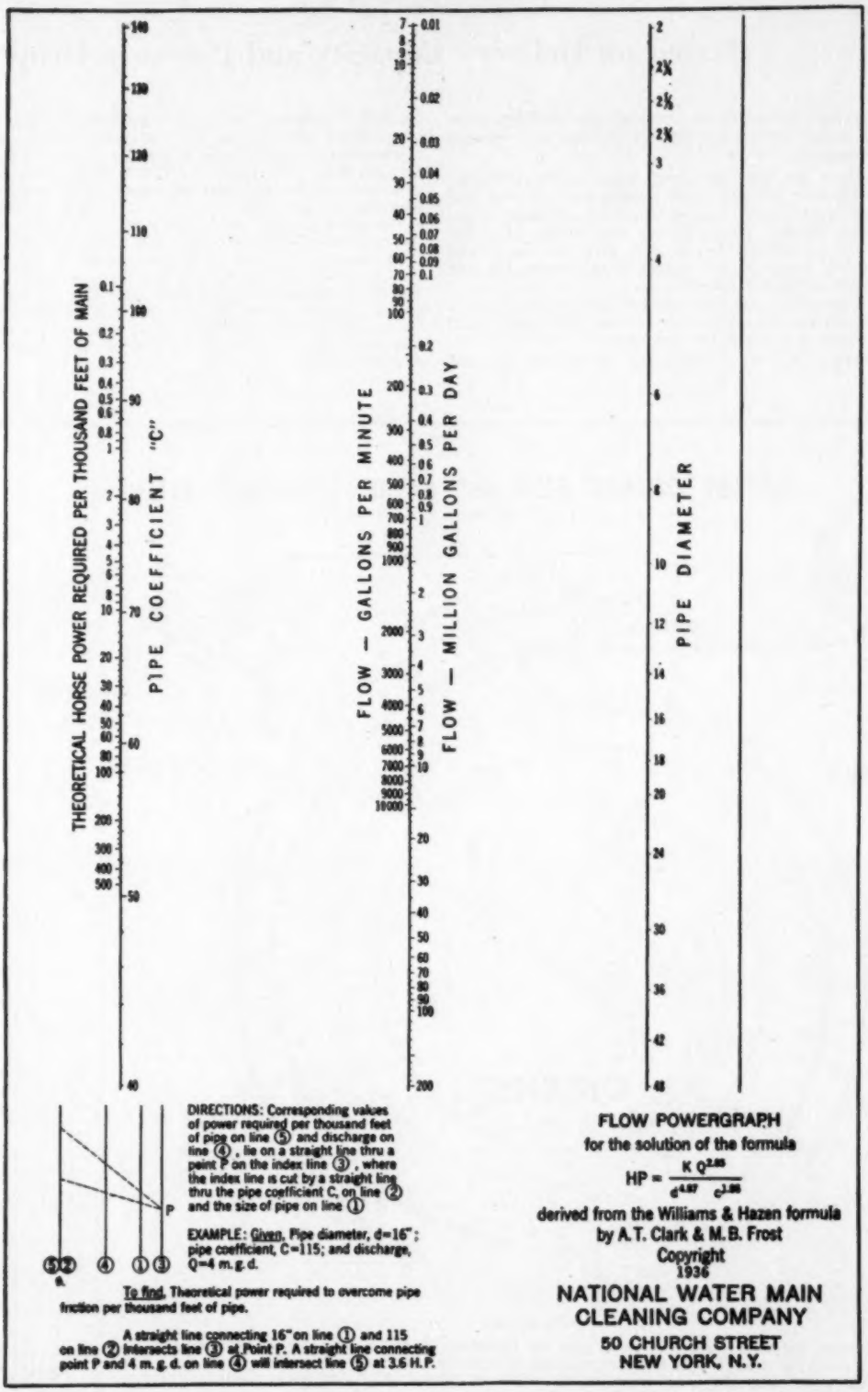
(b) FRICTION COEFFICIENT "C": Determine hydrant discharge rate (M.G.D.) at the end of a section of pipe line. Take simultaneous pressure readings at non-flowing hydrants on the same line several hundred feet ahead. Correct all pressure readings for difference in elevations of gages and calculated friction head loss per 1,000 ft. of intervening pipe*. From flow rates observed and known pipe diameter, follow Example (a) to obtain loss of head which would have resulted with coefficient at "C100." This figure divided into the actual (observed) loss of head reveals the "K" factor and from the useful "C-K" table the coefficient "C" can be approximated. *(Accuracy depends upon use of tested pressure gage, careful flow measurements, and inducing a large loss of head between the non-flowing hydrants. For procedure in making hydrant flow tests, see article by Wilson elsewhere in this Section.)

Directions for Application of This Diagram

(a) FRICTION-HEAD LOSS: A line run from pipe diameter (left vertical) through M.G.D. rates of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipe line; or pressure required per 1,000 ft., in pumping, to overcome such loss due to friction at corresponding line capacity. (If the friction coefficient, due to greater roughness or smoothness of the pipe walls, is other than the base used ["C=100"] multiply the head loss obtained by the corresponding "K" factor given for various "C" values in the "C-K" table on the chart.)

(This diagram is reproduced through courtesy of H. M. Huy and permission of Hydraulic Development Corp. At a location earlier in this Data Section "Practical Methods of Making Flow Tests at Hydrants" are described by P. S. Wilson.)

Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line ① and 115 on line ② intersects line ③ at Point P. A straight line connecting point P and 4 m.g.d. on line ④ will intersect line ⑤ at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
$HP = \frac{K\,Q^{2.85}}{d^{4.87}\ C^{1.85}}$
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN
CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

This Highly Useful Graph Was Devised by Arthur T. Clark and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to Determine Condition of Pipe Lines in Service. (Copies of This Graph on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

Flow through Brass and Copper Pipe

Based on Delivery Capacity and Pressure Drop ▸ ▸ ▸

This chart reveals the correct size of brass pipe or copper pipe or tubing to install for desired delivery of flow and residual pressure requirements.

Since the chart has been developed from reliable formulae, developed at Harvard University for straight runs of brass and copper pipes, it is necessary to allow something additional in the way of friction through valves, elbows and fittings. On this account, for the average service line it is good practice to add 20% to the actual length of run of pipe to compensate for loss of head through valves and fittings.

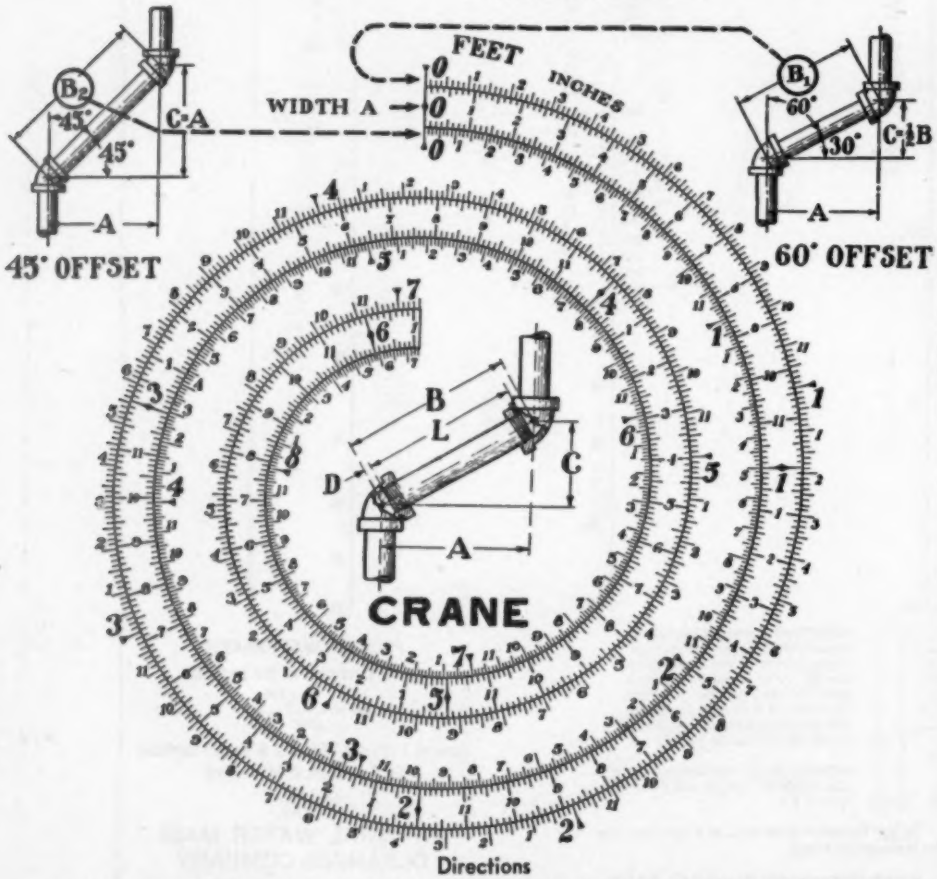
Example: There is an available pressure drop of 30 lbs., and the minimum delivery requirement at fixtures is 35 gals./ min. What size of pipe is required for this service?

Assume a run of 100 ft. to compensate for fittings, etc., add the 20% to secure an "indicated" run of 120 ft. From the 120 ft. point on the base line run up to intersect the down slanting line representing 1 in. pipe; then to the right to the 30 lb. up slanting pressure line; then up to the G.P.M. line. The answer is 36 gals./min. If the ¾ in. size had been tried the result would have been only 17 gals./min. delivery with a 30 lb. pressure available at the main. On the other hand a 1¼ in. line will deliver twice the requirement—i. e., 70 gals./min. Or, for the 35 gal. rate of delivery only 10 lbs. of pressure would be required.

It is evident, therefore, that the chart will reveal the proper size of pipe to deliver a required flow with any desired residual pressure at the outlet. In this case use the difference between the normal minimum pressure at the main and the residual pressure desired as the "available" pressure and proceed as in the example given.

OFFSET CHART FOR 45° & 60° SCREWED FITTINGS

(Copyrighted by Crane Co.)



Pipe size..	⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"
45° deduct.	....	¾"	⅞"	¾"	1"	1⅛"	1⅜"	1⅝"	2"	2"	2⅜"
60° deduct.	....	.....	.....	1"	1⅛"	1⅜"	1⅝"	2"	2⅜"	2½"	3"
Pipe size..	3½"	4"	4½"	5"	6"	7"	8"	9"	10"	12"	
45° deduct.	2⅝"	3⅛"	3⅜"	3¾"	4⅜"	5¼"	5⅞"	6⅝"	7⅜"	8¼"	
60° deduct.	.....	3⅛"	.....	4⅝"	5⅜"	6⅝"	9⅛"	.....	9⅛"	.....	

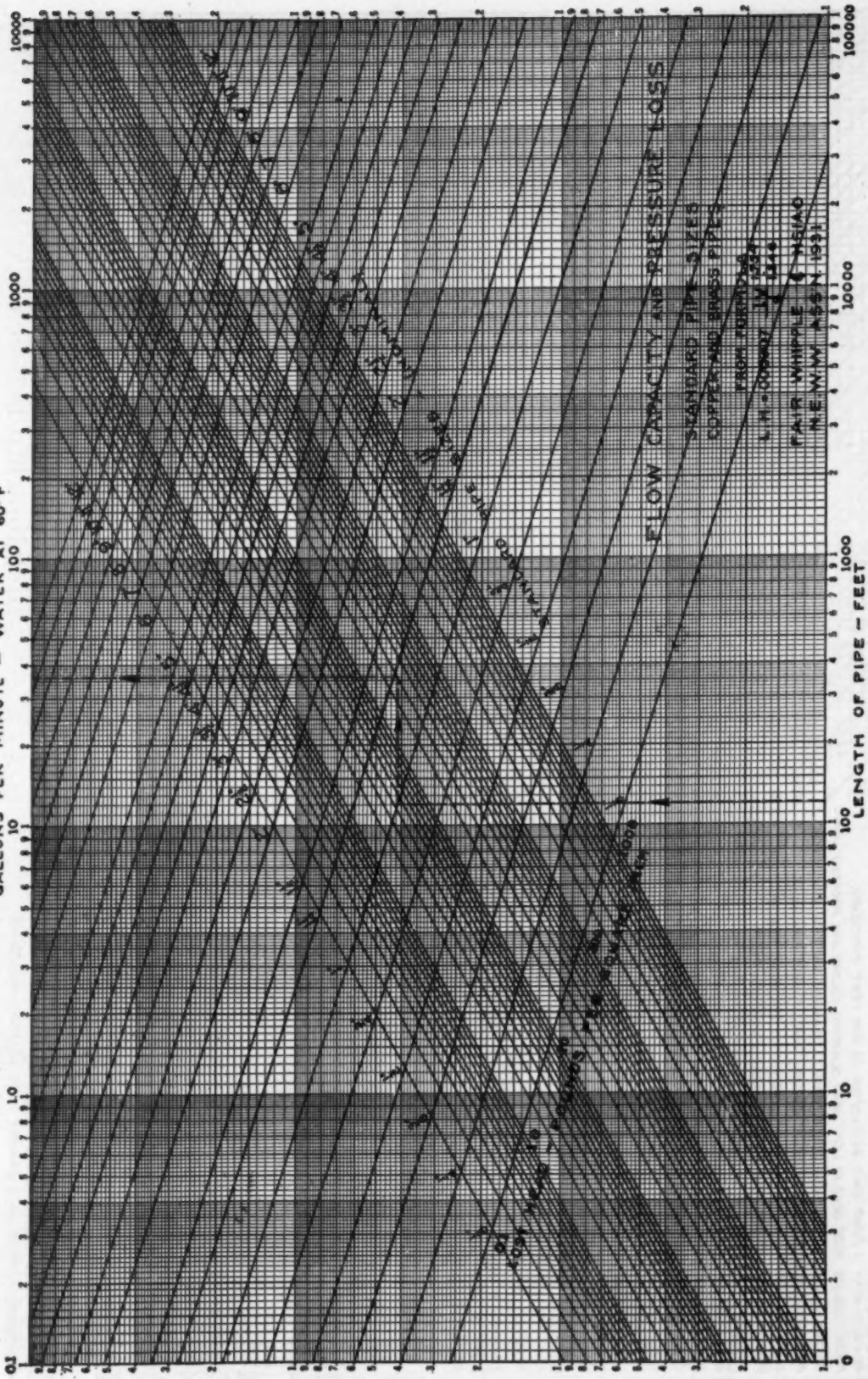
● Note—The above figures represent 2xD. To find D divide by 2. ●

Directions

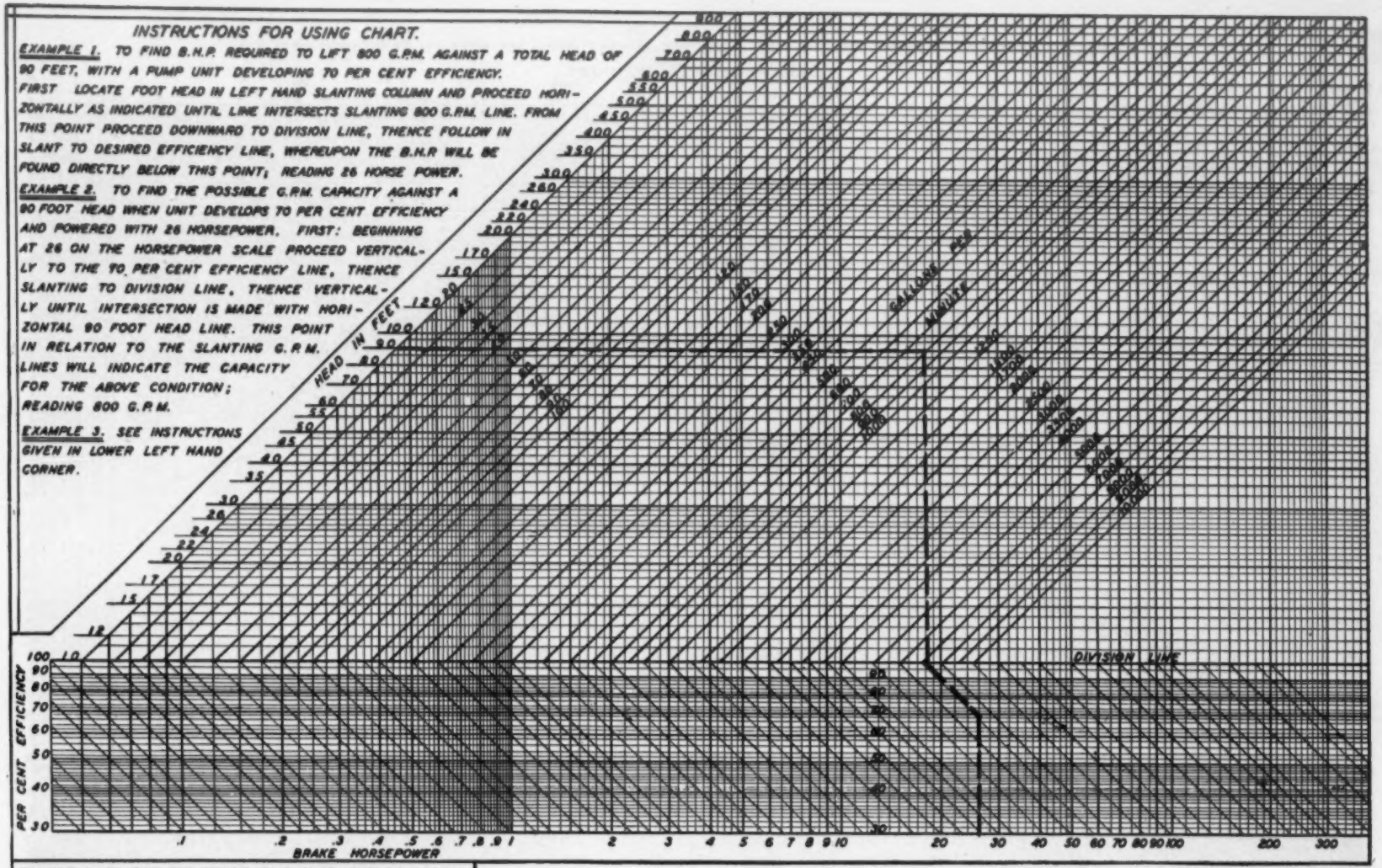
To determine the actual length of pipe, L, to use for length B, find in the table on right the amount to deduct for the desired pipe size and subtract it from length B.

For example, using the above chart, a 45° offset of width 4′-2⅛″ (A) gives the length of run. B as 5′-10⅞″ center to center. If it is a 2″ pipe then the table indicates the amount to deduct is 2″. Subtracting this from 5′-10⅞″ gives 5′-8⅞″ as the length of pipe to cut (L).

DELIVERY CAPACITY AND PRESSURE DROP THROUGH BRASS AND COPPER PIPE


GALLONS PER MINUTE — WATER AT 60° F
LENGTH OF PIPE — FEET
FLOW CAPACITY AND PRESSURE LOSS
STANDARD FULL SIZE PORT
COPPER OR BRASS GLOBE VALVE
FROM "FLOW OF WATER" BY
FAIR, WHIPPLE & HSIAO
NEW YORK 1939
1 1/4" 1 1/2" 2" 2 1/2" 3" 4" 5" 6" 8" 10" 12"

A chart developed by the Brass and Copper Research Association from formulae established at Harvard University


INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Courtesy Peerless Pump Bull.

Relationship between Head, Capacity, Efficiency and Horsepower

Any three known factors determine the fourth

FORMULA FOR AIR FLOW

THE CHART IS BASED ON THE FORMULA:

$$h_{100} = 0.96 \frac{f v^2}{d}$$

WHICH IS A MODIFICATION OF THE WELL-KNOWN DARCY FORMULA FOR TURBULENT FLOW OF FLUIDS.

h_{100} = HEAD LOSS OR PRESSURE DROP PER 100 FT. OF PIPE, IN INCHES OF WATER.

f = HYDRAULIC FRICTION FACTOR DEPENDING ON REYNOLD'S NUMBER AND THE RELATIVE ROUGHNESS OF THE INSIDE BOUNDARY MATERIAL OF THE PIPE. VALUES WERE OBTAINED FROM "FRICTION FACTORS FOR PIPE FLOW", BY MOODY, TRANS. A.S.M.E. VOL. 66 NO. 8, 1944, PP 671-677.

ρ = DENSITY OF AIR AT FLOW CONDITIONS, IN LBS. PER CU. FT.

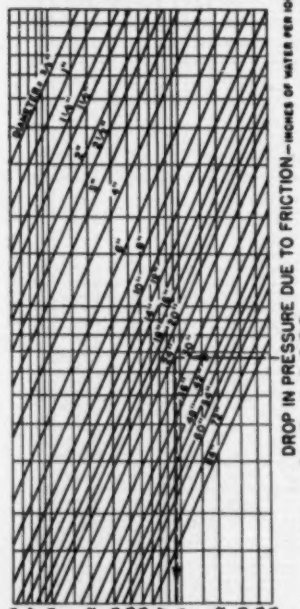
v = THE MEAN VELOCITY OF FLOW, IN FT. PER SEC.

d = INTERNAL DIAMETER OF PIPE, IN INCHES.

CORRECTION FACTORS

THE FOLLOWING TABLE CONTAINS MULTIPLIERS FOR APPROXIMATING THE "DROP IN PRESSURE DUE TO FRICTION" WHEN THE INSIDE PIPE SURFACE DIFFERS FROM THAT ON WHICH CHART IS BASED.

TYPE OF SURFACE	PIPE SIZES		
	3/8"-1 1/4"	1"-30"	24"-84"
WROUGHT IRON, STEEL	0.90-0.95	0.94-0.95	0.81-0.91
GALVANIZED IRON	1.00	1.00-1.05	1.00-1.03
CAST IRON (PLAIN)		1.15-1.35	1.18-1.75
CONCRETE (SMOOTH)			1.20-1.10
CONCRETE (ROUGH)			1.10-1.65
RIVETED STEEL (LIGHT)		1.70-1.90	1.80-1.90
RIVETED STEEL (HEAVY)		1.80-2.00	1.10-2.50
RANGE OF HEAD LOSS TO WHICH FACTORS APPLY	80°-0.1"	80°-0.1"	10°-0.1"



VELOCITY HEAD
INCHES OF WATER

NOMINAL DIAMETER OF PIPE IN INCHES

GALVANIZED PIPE—3/4 TO 2 1/2 INCHES

ASPHALTED CAST-IRON PIPE—3 TO 84 INCHES

DROP IN PRESSURE DUE TO FRICTION—INCHES OF WATER PER 100 FEET OF PIPE

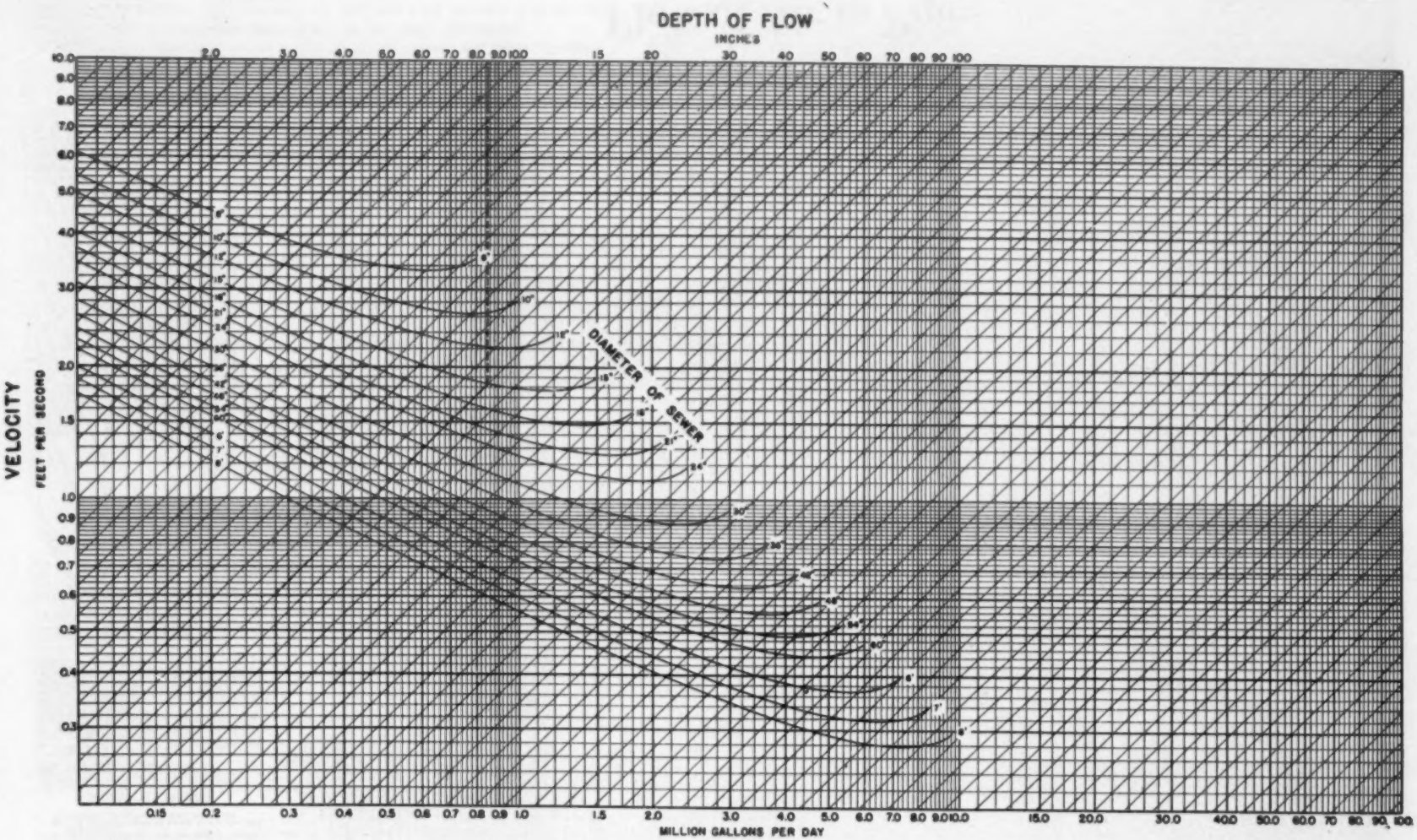
CUBIC FEET OF FREE DRY AIR PER MINUTE
60°F., 29.92" MERCURY, 1 CU. FT. = 0.0764 LBS.

EXAMPLE:

RATE OF FREE AIR	14,000 C.F.M.
DIAMETER OF PIPE	24 INS.
MEAN TEMP. OF AIR IN PIPE	120° F.
MEAN GAGE PRESSURE	5 LBS. PER SQ. IN.
PRESSURE DROP PER 100 FT.	0.67 INS. OF WATER
VELOCITY HEAD	0.91 INS. OF WATER

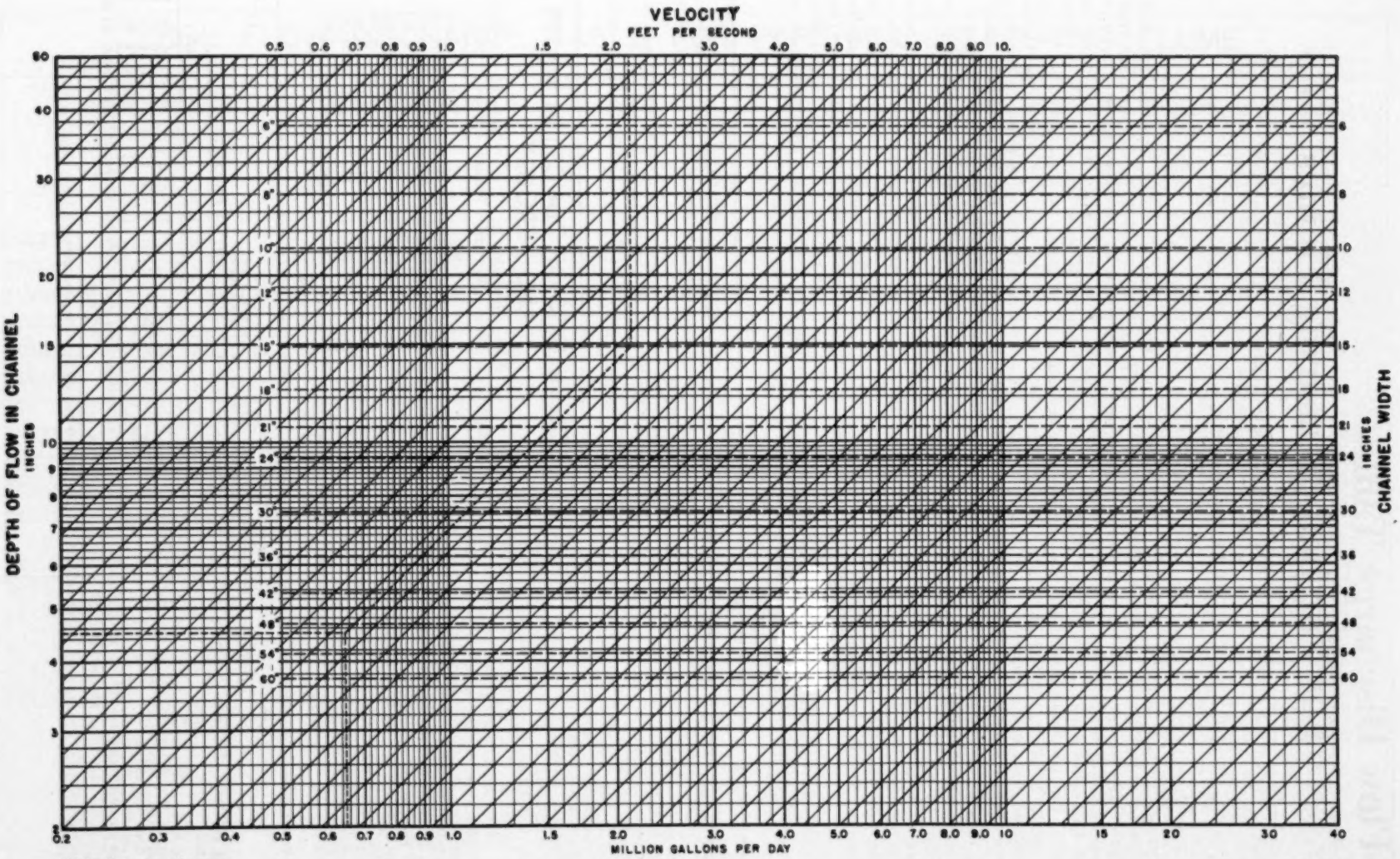
Flow of Air in Pipes

Courtesy of Chicago Pump Co.



Rate of Flow in Circular Sewers

Courtesy of Chicago Pump Co.



EXAMPLE-----------
FLOW- 0.65 M.G.D.
DEPTH FLOW- 4½ INCHES.
CHANNEL- 15 INCHES.
VELOCITY = 2.15 F.P.S.

Rate of Flow in Rectangular Channels

Courtesy of Chicago Pump Co.

Free-Flow Discharge Table For Parshall Measuring Flumes ▸ ▸ ▸

By N. W. NESTER and G. C. HANES
Captain San. Engr.
Corps of Engineers, U. S. Army

THE accompanying table has been prepared to bring together in one place, significant data for use in the determination of free-flow discharge for Parshall measuring flumes of 5 different sizes. This particular chart has found effective use in the 9th Service Command Area where many Parshall flumes are installed.

The basic data for this table were obtained from Farmers' Bulletin No. 1683, published by the U. S. Dept. of Agric. and titled "Measuring Water in Irrigation Channels" by R. L. Parshall, Sr. Irrigation Engr., Div. of Irrigation, Soil Conservation Service.

The table has proved useful as a check on indicating and recording flow meters that have been installed on Parshall flumes. Frequently, discrepancies may be found, as for example, a meter installed on a flume with a throat width larger or smaller than that for which it was designed; or the wrong meter chart may be used.

Testing Float Controlled Meters

In testing the common float-controlled meter, the following method has proved simple but satisfactory. The float is disconnected and a point on the cable is moved by hand from the position where the meter indicates zero flow to the maximum for which the flume was designed, in increments of one inch or one-tenth foot. The point is then moved down the scale so that the meter again indicates zero. The corresponding readings on the meter for each point on the scale are noted. This procedure is repeated several times in order to obtain an average.

The results of these observations are plotted on a graph containing a curve for the throat width (made from data in the accompanying table) on which the meter mechanism is installed. Any discrepancy of the observed data from the correct curve is readily apparent. If the error is large, it is well to plot the curve of another flume of larger or smaller throat width on the same graph. This will usually indicate the design curves of the meter and corrections may be made accordingly.

POWER AND HEAT EQUIVALENTS

1 horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2550 B. T. U. (British thermal units) = 2.64 pounds of water evaporated at 212° F. = 17 pounds of water raised from 62° to 212° F.

1 kilowatt-hour = 1000 watt-hours = 1.34 horsepower-hour = 2,653,200 foot-pounds = 3,600,000 joules = 3420 B. T. U. = 3.54 pounds of water evaporated at 212° F. = 22.8 pounds of water raised from 62° to 212° F.

1 horsepower = 746 watts = 0.746 kilowatt = 33,000 foot-pounds per minute = 550 foot-pounds per second = 2550 B. T. U. per hour = 42.5 B. T. U. per minute = 0.71 B. T. U. per second = 2.64 pounds of water evaporated per hour at 212° F.

1 kilowatt = 1000 watts = 1.34 horsepower = 2,653,200 foot-pounds per hour = 44,220 foot-pounds per minute = 737 foot-pounds per second = 3420 B. T. U. per hour = 57 B. T. U. per minute = 0.95 B. T. U. per second = 3.54 pounds of water evaporated per hour at 212° F.

1 watt = 1 joule per second = 0.00134 horsepower = 0.001 kilowatt = 3.42 B. T. U. per hour = 44.22 foot-pounds per minute = 0.74 foot-pounds per second = 0.0035 pounds of water evaporated per hour at 212° F.

1 B. T. U. (British thermal unit) = 1052 watt-seconds = 778 foot-pounds = 0.252 calorie = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pounds of water evaporated at 212° F.

1 foot-pound = 1.36 joule = 0.000000377 kilowatt-hour = 0.00129 B. T. U. = 0.0000005 horsepower-hour.

1 joule = 1 watt-second = .000000278 kilowatt-hour = 0.00095 B. T. U. = 0.74 foot-pound.

EQUIVALENTS OF OUNCES IN WATER AND MERCURY

Ounces	Inches of Water	Inches of Mercury	Ounces	Inches of Water	Inches of Mercury
.3	.521	.038	8	13.9	1.020
.576	1.0	.073	9	15.6	1.148
1	1.7	.128	10	17.4	1.275
2	3.5	.255	11	19.1	1.403
3	5.2	.383	12	20.8	1.530
4	6.9	.510	13	22.6	1.658
5	8.7	.638	14	24.3	1.785
6	10.4	.765	15	26.3	1.913
7	12.2	.893	16	27.8	2.036

TABLE OF EFFECTIVE FIRE STREAMS

Using 100 feet of 2½-in. ordinary best quality rubber-lined hose between nozzle and hydrant or pump.

Smooth Nozzle, Size	¾ Inch						⅞ inch				
Pressure at Hydrants, lbs.	32	43	54	65	75	86	34	46	57	69	80
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100' 2½" hose	2	3	4	5	5	6	4	6	7	9	10
Vertical Height, feet	48	60	67	72	76	79	49	62	71	77	81
Horizontal Distance, feet	37	44	50	54	58	62	42	49	55	61	66
Gallons Discharged per min.	90	100	116	127	137	147	123	142	159	174	188

Smooth Nozzle, Size	1 Inch						1⅛ Inch				
Pressure at Hydrant, lbs.	37	50	62	73	85	97	41	54	67	80	93
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100' 2½" hose	7	10	12	13	15	17	11	14	17	20	23
Vertical Height, feet	51	64	73	79	85	89	52	65	75	83	88
Horizontal Distance, feet	47	55	61	67	72	76	50	59	66	72	77
Gallons Discharged per min.	161	186	208	228	246	263	206	238	266	291	314

Smooth Nozzle, Size	1¼ Inch						1⅜ Inch				
Pressure at Hydrant, lbs.	46	60	75	90	104	119	52	69	86	102	119
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost per 100' 2½" hose	16	20	25	30	34	39	22	29	36	42	49
Vertical Height, feet	53	67	77	85	91	95	55	69	79	87	92
Horizontal Distance, feet	54	63	70	76	81	85	56	66	73	79	84
Gallons Discharged per min.	253	292	326	357	386	413	307	354	396	434	469

G.C.H. N.W.N.

FREE FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUME

SEC-FT. X .646317 = M.G.D. SEC-FT. X 448.831 = G.P.M.
M.G.D. X 1.54723 = SEC-FT. G.P.M. X .002228 = SEC-FT.

THROAT WIDTH

HEAD		6"			9"			12"			18"			24"		
FT.	IN.	SEC-FT.	G.P.M.	M.G.D.	SEC-FT.	G.P.M.	M.G.D.	SEC-FT.	G.P.M.	M.G.D.	SEC-FT.	G.P.M.	M.G.D.	SEC-FT.	G.P.M.	M.G.D.
0.10	1 3/16	0.05	22.4	0.032	0.09	40.4	.0580									
0.11	1 5/16	0.06	26.9	0.039	0.10	44.9	.0650									
0.12	1 7/16	0.07	31.4	0.045	0.12	53.8	.0775									
0.13	1 9/16	0.08	35.9	0.052	0.14	62.8	.0905									
0.14	1 11/16	0.09	40.4	0.058	0.15	67.3	.0970									
0.15	1 13/16	0.10	44.9	0.065	0.17	76.3	.1100									
0.16	1 15/16	0.11	49.4	0.071	0.19	85.2	.1230									
0.17	2 1/16	0.12	53.8	0.077	0.20	89.8	.1290									
0.18	2 3/16	0.14	62.8	0.090	0.22	98.7	.1420									
0.19	2 1/4	0.15	67.3	0.097	0.24	107.7	.1550									
0.20	2 3/8	0.16	71.8	0.103	0.26	116.9	.1680	0.35	157.1	0.226	0.51	229.0	0.330	0.66	296.3	0.426
0.21	2 1/2	0.18	80.7	0.116	0.28	125.7	.1810	0.37	166.1	0.239	0.55	247.0	0.355	0.71	318.7	0.458
0.22	2 5/8	0.19	85.2	0.123	0.30	134.6	.1940	0.40	179.5	0.259	0.59	265.0	0.381	0.77	345.6	0.498
0.23	2 3/4	0.20	89.8	0.129	0.32	143.6	.2070	0.43	193.0	0.278	0.63	283.0	0.407	0.82	368.0	0.530
0.24	2 7/8	0.22	98.7	0.142	0.35	157.1	.2260	0.46	206.5	0.297	0.67	301.0	0.433	0.88	395.0	0.569
0.25	3	0.23	103.3	0.149	0.37	166.1	.2390	0.49	219.9	0.316	0.71	318.7	0.458	0.93	417.5	0.601
0.26	3 1/8	0.25	112.2	0.162	0.39	175.1	.2520	0.51	229.0	0.330	0.76	341.1	0.491	0.99	444.3	0.640
0.27	3 1/4	0.26	116.9	0.168	0.41	184.0	.2650	0.54	242.5	0.349	0.80	359.0	0.517	1.05	471.3	0.679
0.28	3 3/8	0.28	125.7	0.181	0.44	197.5	.2840	0.58	260.3	0.374	0.85	381.5	0.549	1.11	498.2	0.717
0.29	3 1/2	0.29	130.2	0.187	0.46	206.5	.2970	0.61	274.0	0.394	0.90	404.0	0.582	1.18	530.0	0.763
0.30	3 5/8	0.31	139.2	0.203	0.49	219.9	.3160	0.64	287.3	0.414	0.94	422.0	0.607	1.24	556.6	0.801
0.31	3 3/4	0.32	143.6	0.207	0.51	229.0	.3300	0.68	305.2	0.439	0.99	444.3	0.640	1.30	583.4	0.840
0.32	3 7/8	0.34	152.6	0.220	0.54	242.3	.3490	0.71	318.7	0.458	1.04	466.8	0.672	1.37	615.0	0.886
0.33	3 15/16	0.36	161.5	0.233	0.56	251.3	.3620	0.74	332.0	0.478	1.09	489.0	0.704	1.44	646.0	0.930
0.34	4 1/8	0.38	170.5	0.246	0.59	265.0	.3810	0.77	345.6	0.498	1.14	512.0	0.737	1.50	673.2	0.969
0.35	4 1/4	0.39	175.1	0.252	0.62	278.0	.4010	0.80	359.0	0.517	1.19	534.0	0.769	1.57	705.0	1.015
0.36	4 3/8	0.41	184.0	0.265	0.64	287.3	.4140	0.84	377.0	0.543	1.25	561.0	0.808	1.64	736.0	1.060
0.37	4 1/2	0.43	193.0	0.278	0.67	301.0	.4330	0.88	395.0	0.569	1.30	583.4	0.840	1.72	772.0	1.111
0.38	4 5/8	0.45	201.9	0.291	0.70	314.0	.4520	0.92	412.9	0.594	1.36	610.0	0.879	1.79	803.4	1.156
0.39	4 3/4	0.47	210.9	0.304	0.73	327.6	.4720	0.95	426.0	0.614	1.41	633.0	0.911	1.86	835.0	1.202
0.40	4 7/8	0.48	215.5	0.310	0.76	341.1	.4912	0.99	444.3	0.640	1.47	659.0	0.950	1.93	866.0	1.247
0.41	4 15/16	0.50	224.4	0.323	0.78	350.0	.5040	1.03	462.0	0.666	1.53	686.0	0.989	2.01	902.0	1.299
0.42	5 1/8	0.52	233.3	0.336	0.81	363.5	.5240	1.07	480.0	0.692	1.58	709.0	1.021	2.09	938.0	1.350
0.43	5 3/16	0.54	242.3	0.349	0.84	377.0	.5430	1.11	498.1	0.717	1.64	736.0	1.060	2.16	969.0	1.396
0.44	5 1/4	0.56	251.3	0.362	0.87	390.4	.5620	1.15	516.0	0.743	1.70	763.0	1.098	2.24	1005	1.447
0.45	5 5/16	0.58	260.3	0.375	0.90	404.0	.5820	1.19	534.0	0.769	1.76	790.0	1.137	2.32	1041	1.499
0.46	5 1/2	0.61	274.0	0.394	0.94	422.0	.6075	1.23	552.0	0.795	1.82	816.0	1.176	2.40	1077	1.551
0.47	5 5/8	0.63	283.0	0.407	0.97	435.0	.6270	1.27	570.0	0.821	1.88	843.0	1.215	2.48	1113	1.602
0.48	5 3/4	0.65	292.0	0.420	1.00	448.8	.6460	1.31	588.0	0.847	1.94	870.0	1.254	2.57	1153	1.661
0.49	5 7/8	0.67	301.0	0.433	1.03	462.0	.6660	1.35	606.0	0.872	2.00	898.0	1.293	2.65	1189	1.712
0.50	6	0.69	310.0	0.446	1.06	475.7	.6850	1.39	624.0	0.898	2.06	925.0	1.331	2.73	1225	1.764
0.51	6 1/8	0.71	318.7	0.459	1.10	493.7	.7109	1.44	646.0	0.930	2.13	956.0	1.376	2.82	1266	1.822
0.52	6 1/4	0.73	327.6	0.472	1.13	507.0	.7300	1.48	664.0	0.956	2.19	983.0	1.415	2.90	1301	1.875
0.53	6 3/8	0.76	341.1	0.491	1.16	521.0	.7500	1.52	682.0	0.982	2.25	1010	1.454	2.99	1342	1.932
0.54	6 1/2	0.78	350.0	0.504	1.20	538.0	.7760	1.57	705.0	1.015	2.32	1041	1.499	3.08	1382	1.990
0.55	6 5/8	0.80	359.0	0.517	1.23	552.0	.7950	1.62	727.0	1.047	2.39	1073	1.545	3.17	1422	2.049
0.56	6 3/4	0.82	368.0	0.530	1.26	565.5	.8140	1.66	745.0	1.073	2.45	1099	1.583	3.26	1463	2.107
0.57	6 7/8	0.85	381.5	0.549	1.30	583.4	.8400	1.70	763.0	1.098	2.52	1131	1.628	3.35	1504	2.165
0.58	6 15/16	0.87	390.4	0.562	1.33	597.0	.8600	1.75	786.0	1.131	2.59	1163	1.674	3.44	1544	2.224
0.59	7 1/8	0.89	399.5	0.575	1.37	615.0	.8860	1.80	808.0	1.163	2.66	1194	1.719	3.53	1585	2.282
0.60	7 1/4	0.92	412.9	0.595	1.40	628.0	.9050	1.84	826.0	1.189	2.73	1225	1.764	3.62	1625	2.340
0.61	7 5/16	0.94	422.0	0.608	1.44	646.0	.9300	1.88	843.0	1.215	2.80	1257	1.809	3.72	1670	2.404
0.62	7 7/16	0.97	435.0	0.627	1.48	664.0	.9560	1.93	866.0	1.247	2.87	1290	1.855	3.81	1710	2.463
0.63	7 7/16	0.99	444.3	0.640	1.51	678.0	.9760	1.98	889.0	1.280	2.95	1324	1.907	3.91	1755	2.527
0.64	7 5/8	1.02	457.8	0.659	1.55	696.0	1.002	2.03	911.0	1.312	3.02	1355	1.952	4.01	1800	2.592
0.65	7 11/16	1.04	466.8	0.672	1.59	714.0	1.028	2.08	934.0	1.345	3.09	1387	1.997	4.11	1845	2.656
0.66	7 13/16	1.07	480.0	0.692	1.63	732.0	1.054	2.13	956.0	1.376	3.17	1422	2.049	4.20	1885	2.714
0.67	7 15/16	1.10	493.7	0.711	1.66	745.0	1.073	2.18	978.0	1.409	3.24	1454	2.094	4.30	1930	2.780
0.68	8 1/16	1.12	503.0	0.724	1.70	763.0	1.098	2.23	1001	1.441	3.31	1486	2.140	4.40	1975	2.844
0.69	8 1/4	1.15	516.0	0.743	1.74	781.0	1.125	2.28	1024	1.474	3.39	1522	2.191	4.50	2020	2.908
0.70	8 3/8	1.17	525.1	0.756	1.78	799.0	1.151	2.33	1046	1.506	3.46	1553	2.236	4.60	2065	2.973

HEAD		6"			9"			12"			18"			24"		
FT.	IN.	SEC-FT.	G.P.M.	M.G.D.	SEC-FT.	G.P.M.	M.G.D.	SEC-FT.	G.P.M.	M.G.D.	SEC-FT.	G.P.M.	M.G.D.	SEC-FT.	G.P.M.	M.G.D.
0.71	8 1/2	1.20	538	0.776	1.82	816	1.176	2.38	1068	1.538	3.54	1590	2.288	4.70	2111	3.038
0.72	8 5/8	1.23	552	0.795	1.86	835	1.202	2.43	1091	1.571	3.62	1625	2.340	4.81	2159	3.110
0.73	8 3/4	1.26	566	0.814	1.90	853	1.228	2.48	1113	1.602	3.69	1656	2.385	4.91	2204	3.174
0.74	8 7/8	1.28	575	0.827	1.94	870	1.254	2.53	1136	1.635	3.77	1692	2.437	5.02	2253	3.245
0.75	9	1.31	588	0.847	1.98	889	1.280	2.58	1158	1.667	3.85	1728	2.488	5.12	2300	3.310
0.76	9 1/8	1.34	601	0.866	2.02	907	1.306	2.63	1182	1.700	3.93	1764	2.540	5.23	2347	3.380
0.77	9 1/4	1.36	610	0.879	2.06	925	1.331	2.68	1203	1.732	4.01	1800	2.592	5.34	2397	3.451
0.78	9 3/8	1.39	624	0.898	2.10	943	1.357	2.74	1230	1.771	4.09	1836	2.643	5.44	2442	3.516
0.79	9 1/2	1.42	637	0.918	2.14	960	1.383	2.80	1257	1.809	4.17	1872	2.695	5.55	2491	3.587
0.80	9 5/8	1.45	651	0.937	2.18	978	1.409	2.85	1280	1.842	4.26	1912	2.753	5.66	2540	3.658
0.81	9 3/4	1.48	664	0.957	2.22	996	1.435	2.90	1301	1.875	4.34	1948	2.805	5.77	2597	3.730
0.82	9 7/8	1.50	673	0.970	2.27	1019	1.467	2.96	1329	1.913	4.42	1984	2.857	5.88	2639	3.800
0.83	9 15/16	1.53	686	0.989	2.31	1036	1.493	3.02	1355	1.952	4.50	2020	2.908	6.00	2692	3.878
0.84	10 1/16	1.56	700	1.008	2.35	1054	1.518	3.07	1377	1.984	4.59	2060	2.967	6.11	2742	3.950
0.85	10 3/16	1.59	714	1.028	2.39	1073	1.545	3.12	1400	2.017	4.67	2096	3.018	6.22	2791	4.020
0.86	10 5/16	1.62	727	1.047	2.44	1095	1.577	3.18	1427	2.055	4.76	2136	3.076	6.33	2841	4.091
0.87	10 7/16	1.65	741	1.066	2.48	1113	1.602	3.24	1454	2.094	4.84	2171	3.128	6.44	2891	4.162
0.88	10 9/16	1.68	754	1.085	2.52	1131	1.628	3.29	1476	2.126	4.93	2212	3.186	6.56	2944	4.240
0.89	10 5/8	1.71	768	1.105	2.57	1153	1.661	3.35	1504	2.165	5.01	2248	3.238	6.68	2998	4.318
0.90	10 3/4	1.74	781	1.125	2.61	1171	1.686	3.41	1530	2.203	5.10	2289	3.296	6.80	3052	4.394
0.91	10 7/8	1.77	794	1.144	2.66	1194	1.720	3.46	1553	2.236	5.19	2329	3.354	6.92	3105	4.473
0.92	10 15/16	1.81	812	1.169	2.70	1212	1.745	3.52	1580	2.275	5.28	2370	3.413	7.03	3155	4.543
0.93	11 1/16	1.84	826	1.189	2.75	1234	1.777	3.58	1606	2.313	5.37	2410	3.470	7.15	3209	4.621
0.94	11 1/4	1.87	839	1.208	2.79	1252	1.803	3.64	1633	2.352	5.46	2450	3.529	7.27	3263	4.698
0.95	11 5/16	1.90	853	1.228	2.84	1274	1.835	3.70	1661	2391	5.55	2491	3.587	7.39	3316	4.777
0.96	11 1/2	1.93	866	1.247	2.88	1292	1.862	3.76	1687	2.430	5.64	2531	3.645	7.51	3370	4.853
0.97	11 5/8	1.97	884	1.273	2.93	1315	1.894	3.82	1714	2.468	5.73	2572	3.703	7.63	3425	4.930
0.98	11 3/4	2.00	898	1.293	2.98	1337	1.926	3.88	1741	2.510	5.82	2612	3.762	7.75	3478	5.009
0.99	11 7/8	2.03	911	1.312	3.02	1355	1.952	3.94	1768	2.547	5.91	2653	3.820	7.88	3537	5.093
1.00	12	2.06	925	1.331	3.07	1377	1.984	4.00	1795	2.585	6.00	2692	3.878	8.00	3590	5.170
1.01	12 1/8	2.09	938	1.350	3.12	1400	2.017	4.06	1822	2.624	6.09	2733	3.936	8.12	3645	5.248
1.02	12 1/4	2.12	952	1.370	3.17	1422	2.049	4.12	1849	2.662	6.19	2778	4.000	8.25	3703	5.332
1.03	12 3/8	2.16	969	1.396	3.21	1440	2.074	4.18	1876	2.701	6.28	2818	4.059	8.38	3761	5.416
1.04	12 1/2	2.19	983	1.415	3.26	1463	2.107	4.25	1908	2.747	6.31	2859	4.117	8.50	3815	5.494
1.05	12 5/8	2.22	996	1.435	3.31	1486	2.140	4.31	1934	2.786	6.47	2904	4.182	8.63	3873	5.578
1.06	12 3/4	2.26	1014	1.460	3.36	1508	2.172	4.37	1961	2.824	6.56	2944	4.240	8.76	3932	5.662
1.07	12 7/8	2.29	1027	1.480	3.40	1526	2.197	4.43	1988	2.863	6.66	2989	4.304	8.88	3986	5.740
1.08	12 15/16	2.32	1041	1.500	3.45	1548	2.230	4.50	2020	2.908	6.75	3030	4.362	9.01	4044	5.823
1.09	13 1/16	2.36	1060	1.525	3.50	1571	2.262	4.56	2047	2.947	6.85	3075	4.427	9.14	4102	5.907
1.10	13 1/4	2.40	1077	1.551	3.55	1594	2.295	4.62	2074	2.986	6.95	3119	4.492	9.27	4161	5.991
1.11	13 5/16	2.43	1091	1.571	3.60	1616	2.327	4.68	2101	3.025	7.04	3160	4.550	9.40	4220	6.075
1.12	13 7/16	2.46	1104	1.590	3.65	1638	2.360	4.75	2132	3.070	7.14	3205	4.614	9.54	4282	6.165
1.13	13 9/16	2.50	1122	1.616	3.70	1661	2.391	4.82	2164	3.115	7.24	3250	4.680	9.67	4340	6.250
1.14	13 11/16	2.53	1136	1.635	3.75	1683	2.424	4.88	2190	3.154	7.34	3294	4.744	9.80	4399	6.334
1.15	13 15/16	2.57	1153	1.661	3.80	1706	2.456	4.94	2217	3.193	7.44	3339	4.810	9.94	4461	6.424
1.16	13 15/16	2.60	1167	1.681	3.85	1728	2.490	5.01	2248	3.236	7.54	3384	4.873	10.1	4578	6.528
1.17	14 1/16	2.64	1185	1.706	3.90	1750	2.521	5.08	2280	3.283	7.64	3429	4.940	10.2	4581	6.593
1.18	14 3/16	2.68	1203	1.732	3.95	1773	2.553	5.15	2311	3.329	7.74	3474	5.003	10.3	4623	6.657
1.19	14 1/4	2.71	1217	1.752	4.01	1800	2.592	5.21	2338	3.367	7.84	3519	5.067	10.5	4713	6.786
1.20	14 3/8	2.75	1234	1.777	4.06	1822	2.624	5.28	2370	3.413	7.94	3564	5.132	10.6	4760	6.851
1.21	14 1/2	2.78	1248	1.797	4.11	1845	2.656	5.34	2397	3.451	8.05	3613	5.203	10.8	4850	6.980
1.22	14 5/8	2.82	1266	1.823	4.16	1867	2.688	5.41	2428	3.497	8.15	3658	5.267	10.9	4892	7.045
1.23	14 3/4	2.86	1284	1.848	4.22	1894	2.728	5.48	2460	3.542	8.25	3703	5.332	11.0	4940	7.110
1.24	14 7/8	2.89	1297	1.867	4.27	1917	2.760	5.55	2491	3.587	8.36	3752	5.403	11.2	5027	7.240
1.25	15	2.93	1315	1.894	4.32	1939	2.793	5.62	2522	3.632	8.46	3800	5.468	11.3	5072	7.304
1.26	15 1/8	2.97	1333	1.920	4.37	1961	2.824	5.69	2554	3.678	8.56	3842	5.533	11.5	5162	7.433
1.27	15 1/4	3.01	1350	1.945	4.43	1988	2.863	5.76	2585	3.723	8.67	3892	5.603	11.6	5210	7.497
1.28	15 3/8	3.04	1364	1.965	4.48	2011	2.896	5.82	2612	3.762	8.77	3936	5.666	11.7	5251	7.562
1.29	15 1/2	3.08	1382	1.991	4.53	2033	2.928	5.89	2644	3.807	8.86	3986	5.740	11.9	5341	7.691
1.30	15 5/8	3.12	1400	2.017	4.59	2060	2.967	5.96	2675	3.852	8.99	4035	5.810	12.0	5386	7.756
1.31	15 3/4	3.16	1418	2.042	4.64	2083	3.000	6.03	2710	3.900	9.09	4080	5.875	12.2	5476	7.885

W. & S. W.—REFERENCE & DATA—1954

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Conversion Factors

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc., respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., Stamford, Conn.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Conversion of °C to °F or °F to °C $= \frac{C}{100} = \frac{F - 32}{180}$

Weights and Measures

Troy Weight

3.086 grains = 1 carat
24 grains = 1 dwt.
20 dwts. = 1 ounce
12 ounces = 1 pound

Used for weighing gold, silver, and jewels.

Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound

The ounce and pound in this weight are the same as in Troy Weight.

Avoirdupois Weight

1 grain (Troy) = 1 grain (Apoth.) = 1 grain (Avdp.)

27 11/32 grams = 1 dram
16 drams = 1 ounce = 437.5 grains
16 ounces = 1 pound
25 pounds = 1 quarter
4 quarters = 1 cwt.
2,000 lbs. = 1 short ton
2,240 lbs. = 1 long ton
1 long ton = 1 British ton

Dry Measure

2 pints = 1 quart
1 quart = 67.2 cu. in.
8 quarts = 1 peck
4 pecks = 1 bushel
1 British bushel = 1.032 U. S. Bushel

Liquid Measure

4 gills = 1 pint
16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
1 gallon = 231 cu. in.
31½ gallons = 1 barrel
2 barrels = 1 hogshead

1 British Imperial gallon = 1.200 U. S. gallons
1 cubic foot of water contains 7.48 gallons and weighs 62.321 lb.

Linear Measure

1 mil = 0.001 inch
12 inches = 1 foot
3 feet = 1 yard
5½ yards = 1 rod
40 rods = 1 furlong
8 furlongs = 1 statute mile
5280 feet = 1 statute mile
3 miles = 1 league

Square Measure

1 circular mil = 0.7854 square mils
1,000,000 square mils = 1 square inch
144 square inches = 1 sq. ft.
9 sq. ft. = 1 sq. yard
4 roods = 1 acre = 43560 sq. ft.
30¼ sq. yds. = 1 sq. rod
40 sq. rods = 1 rood
640 acres = 1 sq. mile

Surveyor's Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods = 1 chain
43560 sq. ft. = 1 acre
640 acres = 1 sq. mile
10 sq. chains or 160 sq. rods = 1 acre
36 sq. miles (6 miles square) = 1 township

Mariners' Measure

6.08 feet = 1 fathom
120 fathoms = 1 cable length
8.31 cable lengths = 1 nautical mile
6080 feet = 1 nautical mile
1 nautical mile = 1.15 statute mile
1 knot is a speed of 1 nautical mile per hour

Paper Measure

24 sheets = 1 quire
20 quires = 1 ream
2 reams = 1 bundle
5 bundles = 1 bale

Cubic Measure

1 cu. cm. = .061 cu. in.
27 cu. ft. = 1 cp. yd.
40 cu. ft. = 1 ton (shipping)
231 cu. in. = 1 standard gallon
2150.42 cu. in. = 1 standard bushel
1 cu. ft. = 4/5 of a bushel
1728 cu. in. = 1 cu. ft.
128 cu. ft. = 1 cord (wood)

Household Measure

60 drops = 1 teaspoon
2 teaspoons = 1 dessert spoon
3 teaspoons = 1 tablespoon
16 tablespoons = 1 cup
2 gills = 1 cup
2 cups = 1 pint

METRIC EQUIVALENTS

Linear Measure

1 millimeter = 0.03937 inches
1 centimeter = 0.3937 inches
1 decimeter = 3.937 in. = 0.328 ft.
1 meter = 39.37 in. = 1.0936 yards
1 dekameter = 1.9884 rods
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters
1 foot = 3.048 decimeters
1 rod = 0.5029 dekameter
1 yard = 0.9144 meter
1 mile = 1.6093 kilometers

Square Measure

1 sq. cm. = 0.1550 sq. in.
1 sq. decimeter = 0.1076 sq. ft.
1 sq. meter = 1.196 sq. yds.
1 hectare = 2.47 acres
1 sq. kilometer = 0.386 sq. miles
1 sq. in. = 6.452 sq. cm.
1 sq. foot = 9,2903 sq. decimeters
1 sq. yard = 0.8361 sq. meter
1 sq. mile = 2.59 sq. kilometers

Weights

1 dyne = .00102 grains
1 gram = 0.03527 ounces
1 kilogram = 2.2046 lbs.
1 metric ton = 2205 lbs.
1 pound = 0.4536 kilograms
1 metric ton = 1.1023 short tons
1 ounce = 28.35 grams = 437.5 grains

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